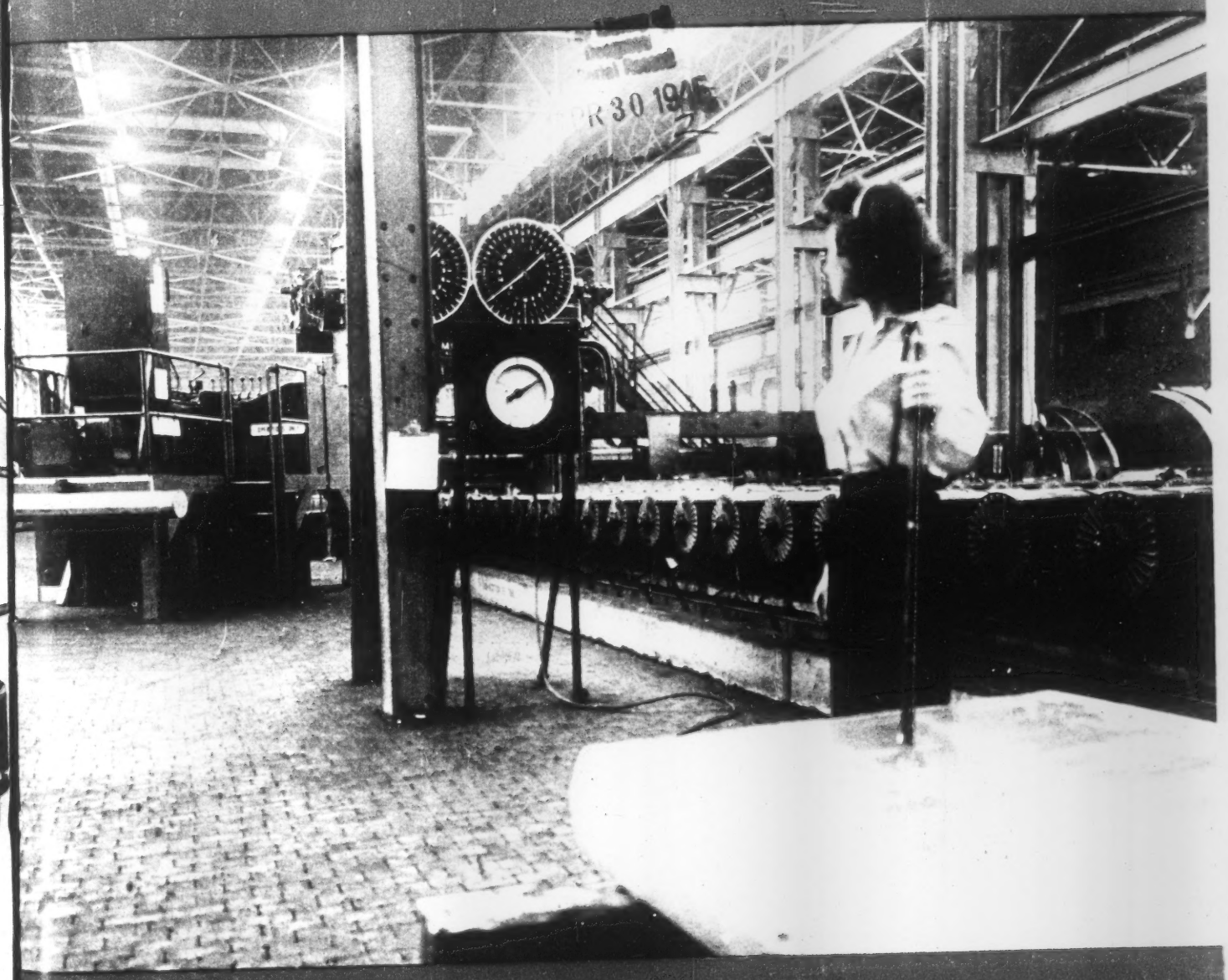
Instruments

THE MAGAZINE OF

Measurement and Control

VOL. 18
MAR.
1945
NO. 3



INCLUDING Aviation Instruments

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TAG

Indicating and Recording Instruments for a Wide Range of Industrial Process Control . . . . . .

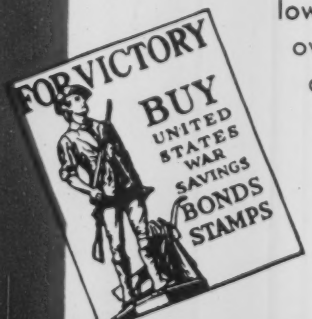
Today, thousands of TAG Recording and Controlling Instruments are in effective service in the synthetic rubber, chemical catalytic cracking, aeroplane engine testing, ordnance, and food fields. Now, when uninterrupted production is vital—where needless reruns would set back the war effort—you particularly need the well demonstrated control efficiency that TAG provides.

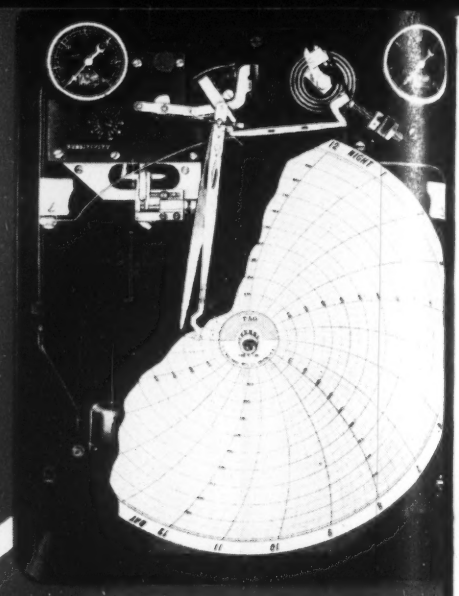
The TAG High Sensitivity (On-Off) Recorder-Controller is a popular instrument because it is simple in construction and does its work well on most industrial applications where process time lag is small and the heat capacity is large.

The TAG Fall Range Throttling Recorder-Controller is ideally suited to processes where load changes are small and of short duration. In addition to the control unit, this instrument utilizes a full range throttling flapper mechanism and is recommended for use on applications of considerable process lag, or of small heat capacities.

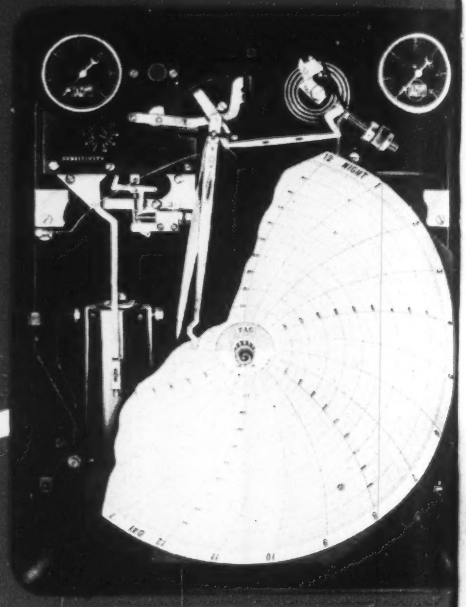
The TAG Full Range Throttling Recorder-Controller with Automatic reset is designed for difficult control applications where large load changes that extend over a long period are encountered. This design lowers the control sensitivity and prevents over-controlling or hunting. And, because of this reset feature, the Controller will not shift from the set point.

Catalog No. 1200-I will give you complete information.

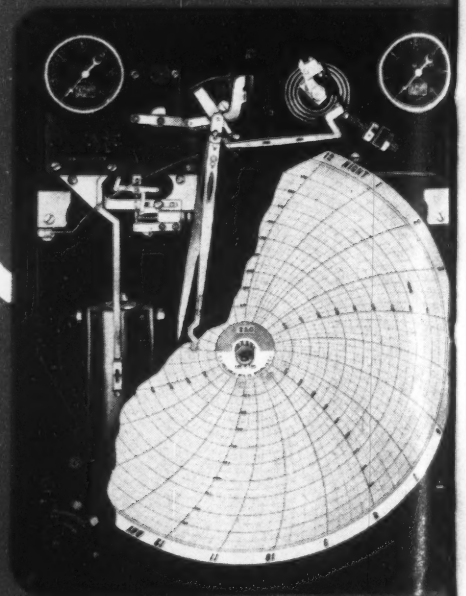




TAG High Sensitivity (On-Off) Recorder-Controller



TAG Full-Range Throttling Recorder-Contr



TAG Full-Range Throttling Recorder-Contr with Automatic Reset

PORTABLE PRODUCTS CORPORATION

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TAG

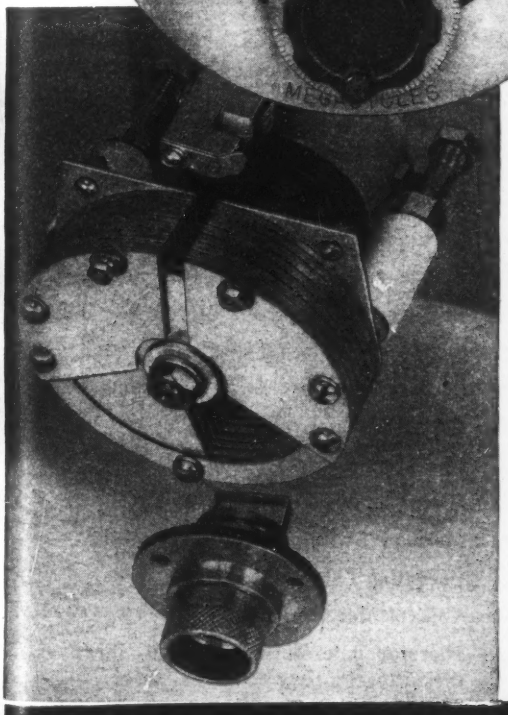
Instruments for Indicating Recording and Controlling

PARK & NOSTRAND AVES., BROOKLYN 5, N. Y.

NEW OSCILLATOR

100 To 500 Mc

THIS NEW oscillator, designed for use as a general-purpose laboratory instrument, uses the new Butterfly Circuit which obviates the difficulty of sliding contacts in any part of the circuit and provides a source of ultra-high-frequency power sufficient for most laboratory measurement needs.



Some of its features are:

- Dial calibrated directly in megacycles with an accuracy of 1 per cent.
- Vernier dial with 100 divisions, covering the turning range in 10 turns.
- Output through a coaxial jack to which is attached a pick-up loop to provide variable coupling to the oscillator.
- Output of one-half watt with the power supply furnished.
- Output up to one watt at the highest frequency with a 450-volt power supply, provided certain precautions are taken in the operation of the oscillator.
- The Type 857-P1 Power Supply furnishes a plate voltage of 350 volts and filament supply of 2.5 volts for the W. E. Type 316-A tube used in the oscillator.
- Electron-ray tube incorporated in the power supply to show oscillator grid current.

Type 857-A Oscillator with Type 857-P1 Power Supply $250.00

We are in limited production now for high priority war orders; reservation orders for later deliveries are being accepted.

A complete description appears in the G-R Experimenter for November, 1944. If you do not have a copy, write for Bulletin 932.

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Prompt Deliveries

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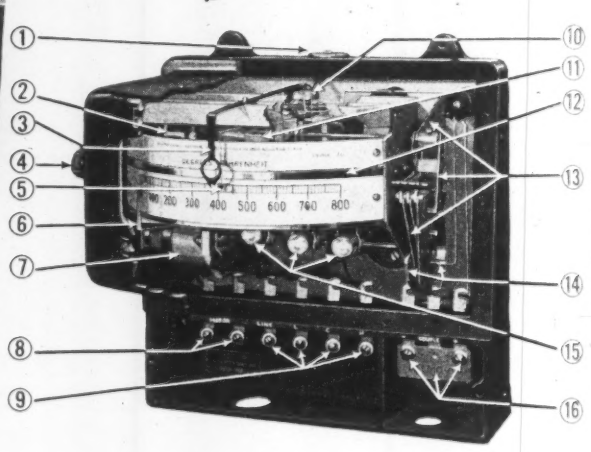

Whether you heat treat steel dies, anneal, harden or temper metal products—make die castings, bake enamel or do galvanizing—if you work with temperature, your materials, your furnaces, your time and money are staked on—Accurate Temperature Control.

Where temperatures fluctuate, quality of product is bound to suffer—spoilage increases and costs go up.

That is why War Plants in the metal working industries are turning to Brown Indicating Control Pyrometers for efficient control of furnaces and ovens, etc.—electric, oil or gas fired.

The Brown Indicating Control Pyrometer maintains its accuracy where unusual shocks, vibrations and other adverse conditions are encountered.

In the control circuits of this pyrometer there are no open contacts. Con-Tac-Tor Mercury Switches make and break all circuits and eliminate the use of relays for most applications.

To insure low cost furnace operation, minimize rejects, and hold uniform quality—install Brown Indicating Control Pyrometer. Standard scale temperature ranges carried in stock make possible prompt shipment.

Write for catalog. THE BROWN INSTRUMENT COMPANY, a division of Minneapolis-Honeywell Regulator Co., 4482 Wayne Avenue, Philadelphia 44, Pa. Offices in all principal cities. 119 Peter Street, Toronto, Canada; Wadsworth Road, Perivale, Middlesex, England; Nybrokajen 7, Stockholm, Sweden.

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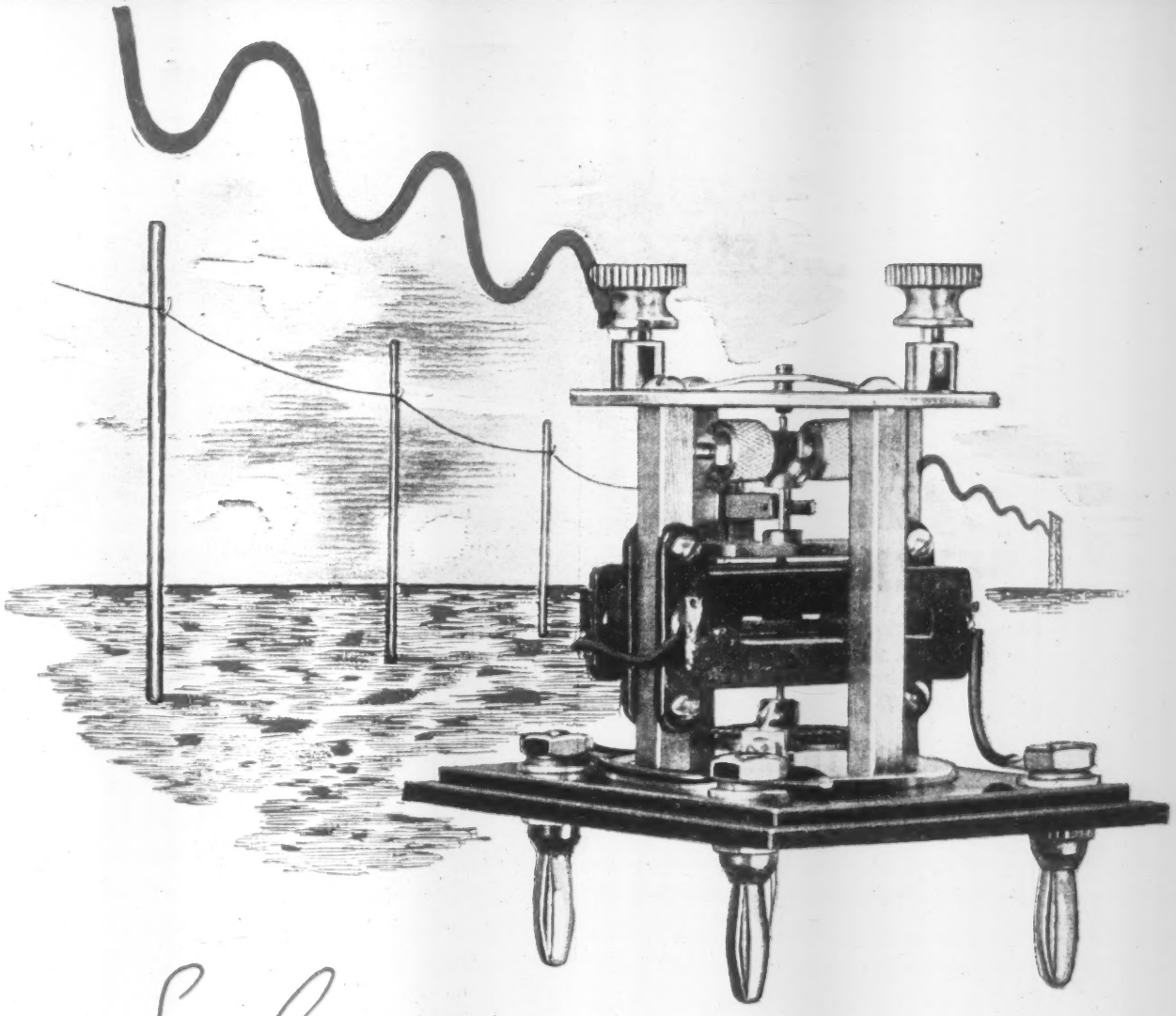
2. Safety Control Table
3. Control Index
4. Knob for Control Setting
5. Duralumin Pointer
6. Compensating Index for Zero Setting
7. Enclosed Synchronous Motor Non-Oiling
8. Enclosed Motor Terminals
9. Enclosed Mercury Switch Terminals
10. Galvanometer System
11. Operating Control Table
12. Mirror
13. Mercury Switch Selector Levers
14. Operating Cam
15. Control Mercury Switches
16. Thermocouple Terminals with Short Circuiting Plate

BROWN PYROMETER CONTROLLERS



REMOTE *Single Carrier* **CONTROL**

EITHER CONDUCTOR OR RADIO WAVE

of variable sequence operations becomes an "everyday" procedure with W&T Torsional Relays.

Of particular interest to the engineer are a few design characteristics: **RANGE** — 10 to 20 cycles per second. **SENSITIVITY** — Less than 3.0 seconds from impression of a 5 volt 0.0012 ampere current pulse of constant amplitude and at the resonant frequency to which the relay is adjusted. **SELECTIVITY** — Resonant frequency plus or minus 2.5% under above conditions for response. **STABILITY** — Excellent over a wide range of ambient temperature and pressure. **CONTACT CAPACITY** — In controlled circuit, 50 milliamperes.

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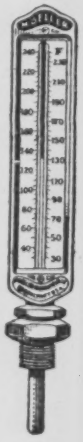
A-38

MOELLER



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The lasting accuracy, ruggedness and other distinctive features of Moeller Instruments are the result of the thoroughly precise and honest way they are engineered.

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Extreme Precision Grade: Solid glass etched stem, mercury thermometers (nitrogen filled) for determining temperatures within a fractional part of a degree.

Standard Thermometers: Provide laboratory accuracy combined with sturdiness. Made of highest grade glass and materials. Mercury filled, calibrated for total or partial immersion. Types with "Moeller Glass Red Reading Column" afford optimum ease in reading.

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Vol. 18 MARCH 1945 No. 3

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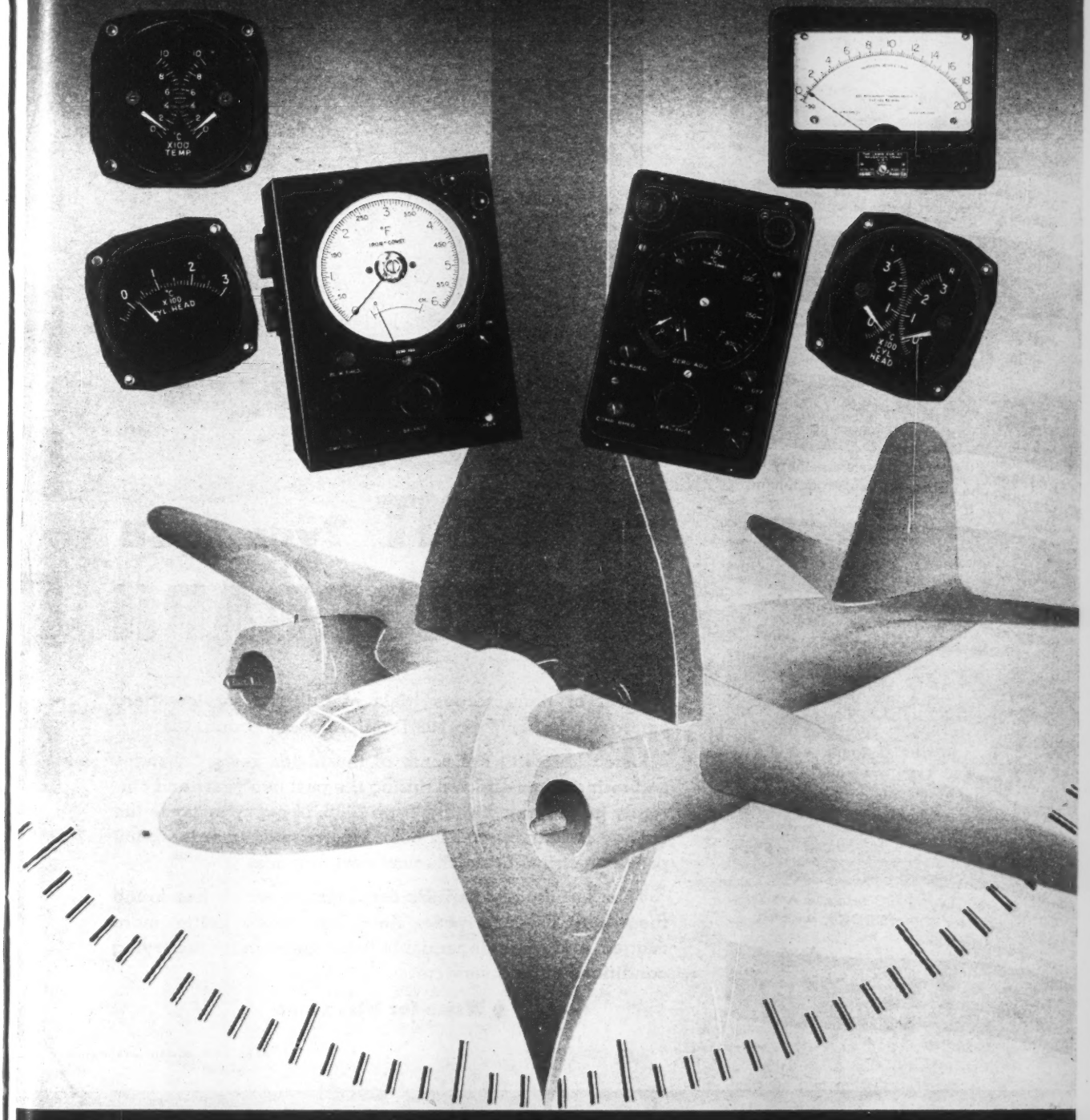

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Use of mineral-oil-impregnated, hermetically-sealed, paper capacitors.

Increase in voltage rating of certain capacitors for greater factor of safety.

Addition of mounting straps on capacitors subject to breakage in transit.

Use of high-voltage wire in high-voltage circuits in place of previous standard wire.

Addition of tube clamps for tubes subject to jarring loose in transit.

Addition of flange on chassis assembly to provide extra strength against rough handling.

Addition of four bank supports to prevent breakage of banks during rough handling.

Numerous mechanical refinements – better sockets, elastic stop nuts, rolled bead on cathode-ray tube shield, additional brackets.

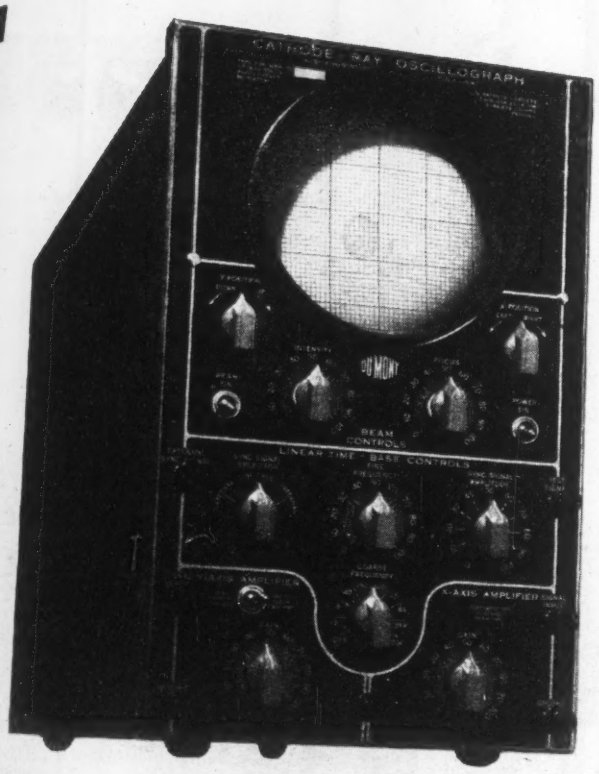
Change of negative rectifier from Type IV to Army-Navy preferred Type 6X5GT/G.

Change from ¼-watt neon tube to Army-Navy preferred Type 991 voltage regulator tube for greater stability.

Inclusion of frequency range adjustment potentiometer in time base as a factory adjustment, for accurate time-base frequency setting.

Change from Type 6F8G tubes to Army-Navy preferred Type 6SN7GT, with improved performance.

All composition resistors operated at less than 40% of power rating; capacitors at less than 80% of voltage rating.



DuMONT Type 208B OSCILLOGRAPH

Out of the rigorous trials of military service there emerges a better Type 208 DuMont Oscillograph.

Listed herewith are some of the major design changes and refinements effected during the past two years and currently incorporated in the Type 208B. In every instance the change or refinement has been incorporated in order to improve electrical or mechanical performance.

Thus an already popular oscillograph which has found the widest usage in peace times becomes a better, more rugged, and more dependable instrument under the trying conditions of field service.

Write for literature

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DUMONT *Precision Electronics & Television*

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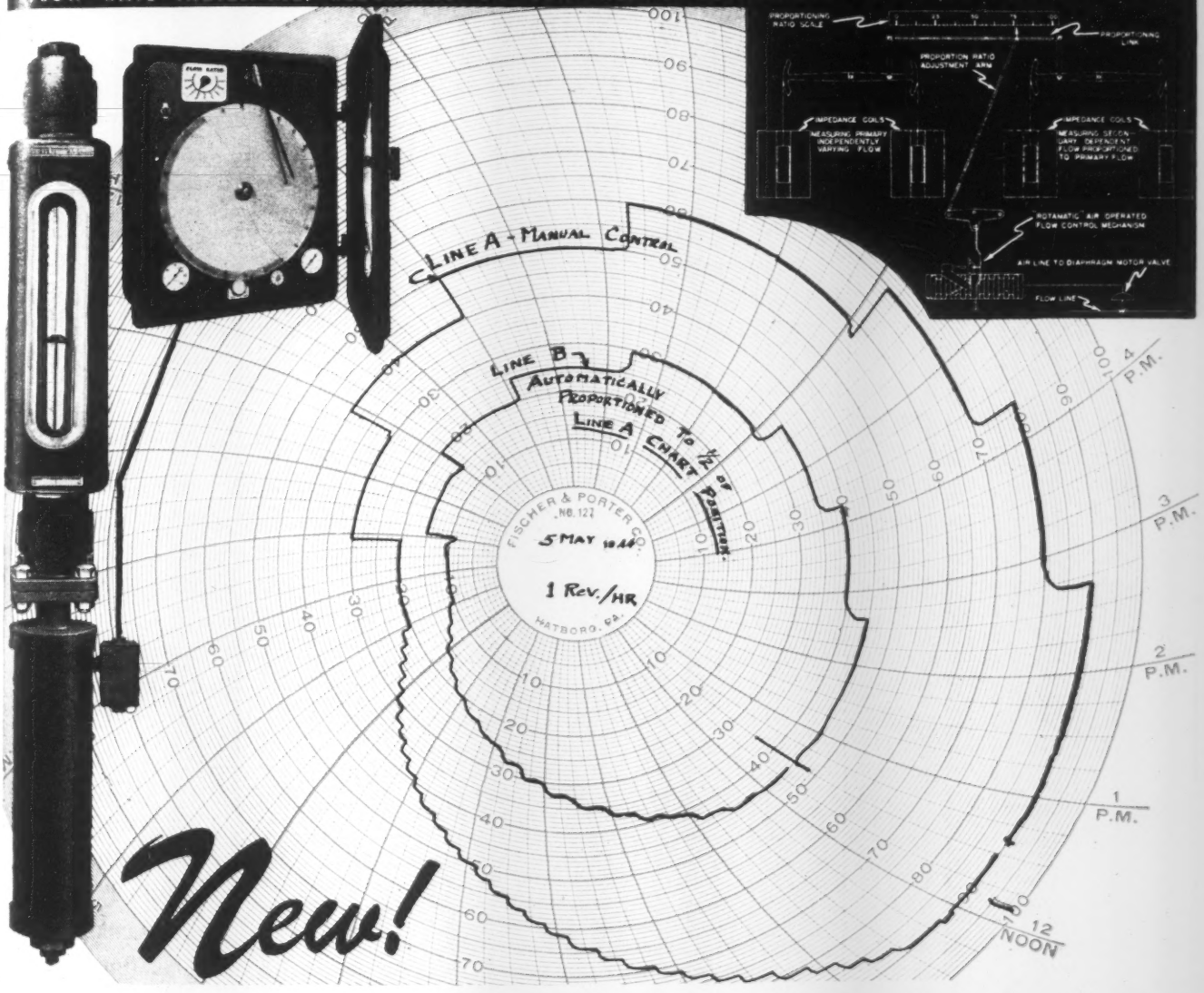
FLOW RATE INDICATING, RECORDING OR CONTROLLING ROTAMETERS FOR ANY LIQUID OR GAS



New!

ROTAMETER FLOW RATIO CONTROLLER

automatically proportions two flows with high accuracy!

If you have a ratio flow control problem where you wish to keep one flow at a fixed percentage of a second *variable* flow, the new Rotamatic Ratio Flow Controller will do the job automatically for you. Furthermore the ratio may be varied at will by a turn of the flow ratio button. The device for doing this remarkable job of proportional control is so simple and so positive that what was once a difficult control problem has become easy and also reasonable in price.

In the flow chart shown above, the ratio index button has been set for proportioning at 1:2. Notice how accurately this proportion has been maintained, in spite of rapid flow fluctuations and variations over the full flow range of the rotameters.

The Ratio Controller operates as follows: Two rotameters with electric transmission for remote reading are placed in the respective flow streams. The remote flow-responsive balance beams from these two rotameters are placed back to back and connected by a cross beam, as shown in the above sketch. From this cross beam is suspended an arm whose position may be changed at will by sliding it on the beam. This suspension arm is connected to a Rotamatic air-operated control mechanism which in turn transmits air pressure to an air-operated valve in the flow line of the stream which is to be maintained at a fixed percentage of the main flow. It can be seen that the position of the arm suspended on the cross beam determines the control point or in other words, the flow ratio of one stream to the other. Liquid flows from 1GPM up to 6,000 GPM may be proportioned, and gas flows in equivalent volumes.

The full and interesting details in regard to the new Rotamatic Ratio Controller are told in our bulletin 50-A which we will send to you without any obligation. Owing to the paper shortage, please make your request upon your Company letterhead. Write to FISCHER & PORTER COMPANY, 2303 County Line Road, Hatboro, Pa.

F.P. ROTAMETERS

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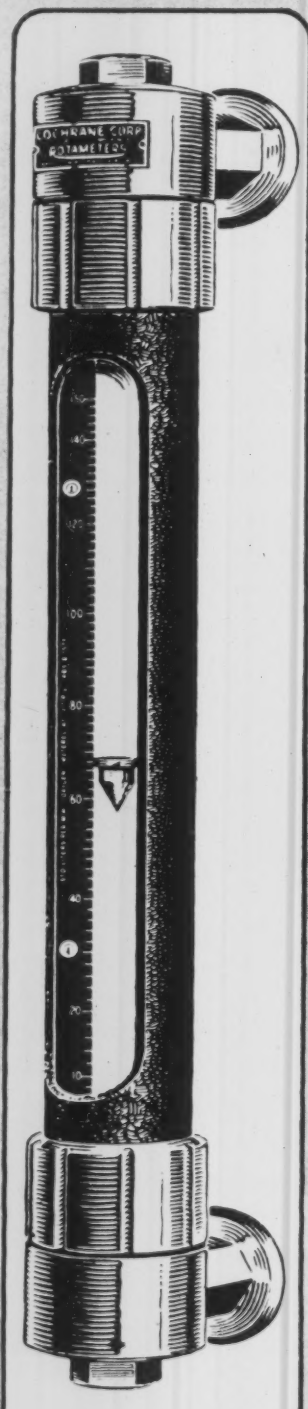
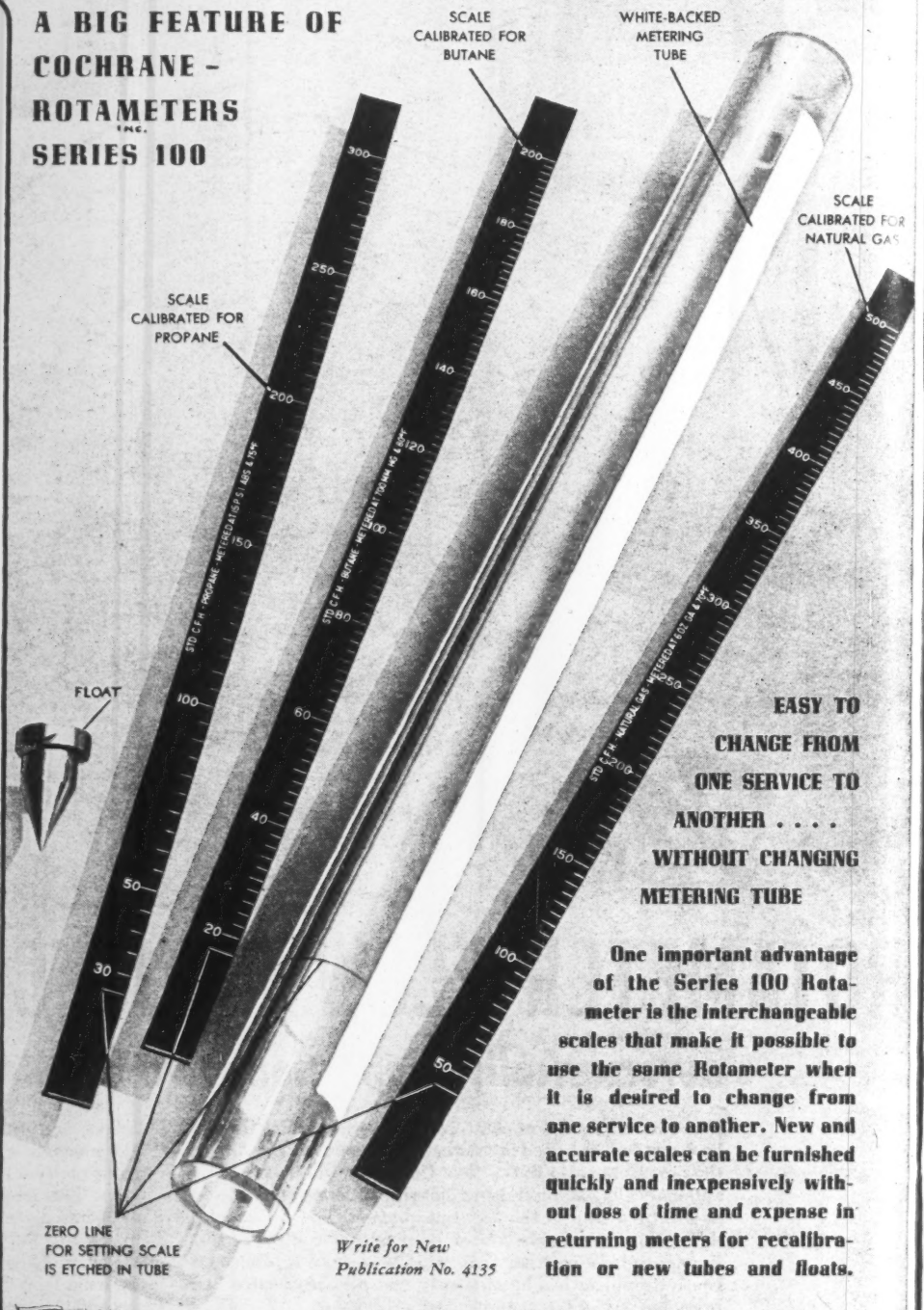
INTERCHANGEABILITY



A BIG FEATURE OF COCHRANE – ROTAMETERS INC. SERIES 100


SCALE CALIBRATED FOR BUTANE
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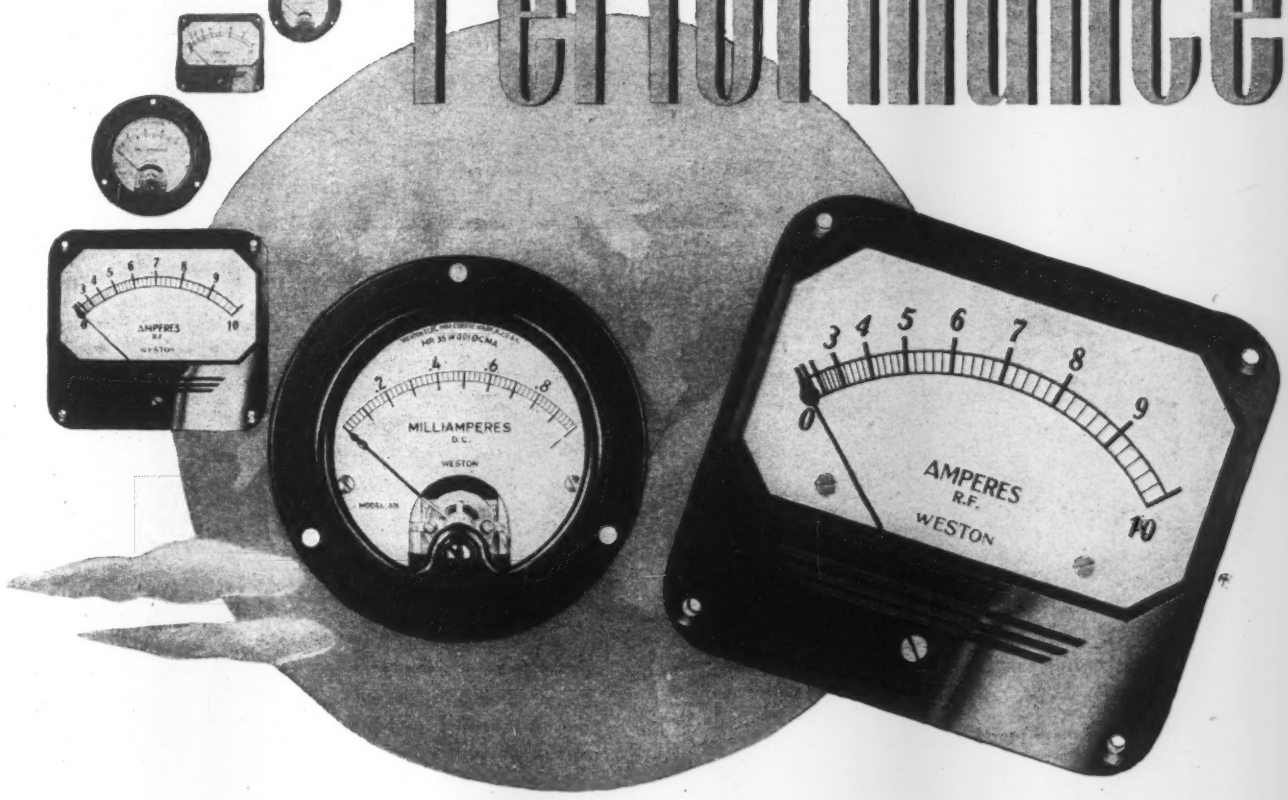

for destinations known or unknown

Today, our electrical equipment encircles the globe; some serving at Greenland's ice cap or in Kiska's fogs . . . others stewing in the swamps of a Pacific atoll.

With the destinations of war-products totally unknown, manufacturers logically have preferred "building-in" WESTONS on their control panels. They know that a WESTON will perform dependably *anywhere* . . . that there is sound reason behind WESTONS acceptance as the *international standard.*

And tomorrow, with equipment reaching known markets, instrument preferences will remain unchanged. For while human life no longer will be at stake, *reputations will.* So manufacturers will continue to "build-in" the instruments which consistently tell-the-truth . . . to build broader market acceptance and customer good-will, and assure highest efficiency from the machines which bear their name.

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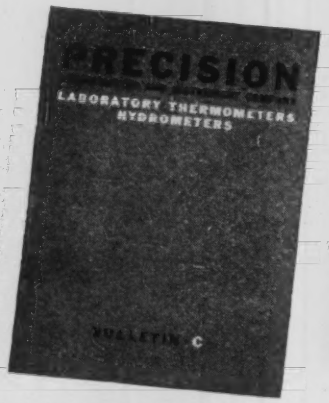
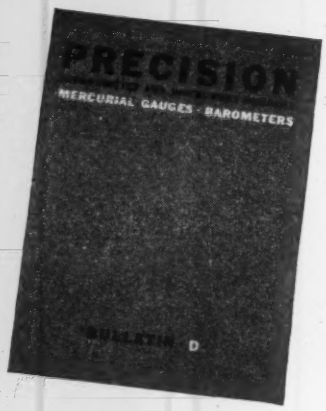


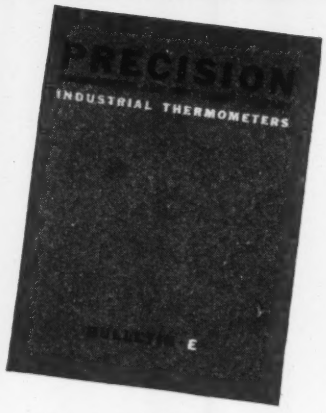
Princo Laboratory Instruments

The complete line of PRINCO instruments for laboratory testing and control, including instruments specifically designed for chemical, petroleum, sugar, alcohol and "spirits," and other industrial control and testing. Comprehensive data on Society Specification and Special Test Thermometers, Test Wells, various Armored Thermometers, Hydrometers, etc., are contained in Bulletin C.



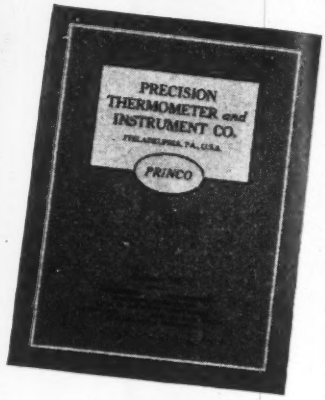
Gauges, Barometers, Manometers, Gravitometers

Here is your complete reference to PRINCO Manometers and associated instruments for specialized applications in a wide variety of fields. Marine and Ballistic instruments; Absolute Pressure Gauges; Vacuum, Draft and Mercury Gauges; Altitude Standards, etc., are described and illustrated in PRINCO Bulletin D.



Princo Industrial Thermometers

Power plants, chemical and process industries, refrigeration, air conditioning, food, mills, warehouses, paint and varnish manufacture, pipe lines, pumps, stills and boilers— PRINCO instruments serve these and countless other varied and exacting industrial applications. Complete data in Bulletin E.



Princo Meteorological and Agricultural Instruments

In Bulletin H, you will find the highly accurate instruments designed by PRINCO to the exacting standards of this science. Included are Rain and Snow Gauges, Soil Thermometers, Hygrometers, Hygroscopes, Psychrometers, Barometers, Orchard and Orchard Alarm Thermometers and Thermostats.

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HERE, in easy to use form, are facts about the complete line of PRINCO Mercurial Thermometers and related instruments.

Write today for a copy of any one or all of those described above — or for convenience check those which you desire and send this page to us with your name attached.

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KNOW-HOW BEGINS AT HOME

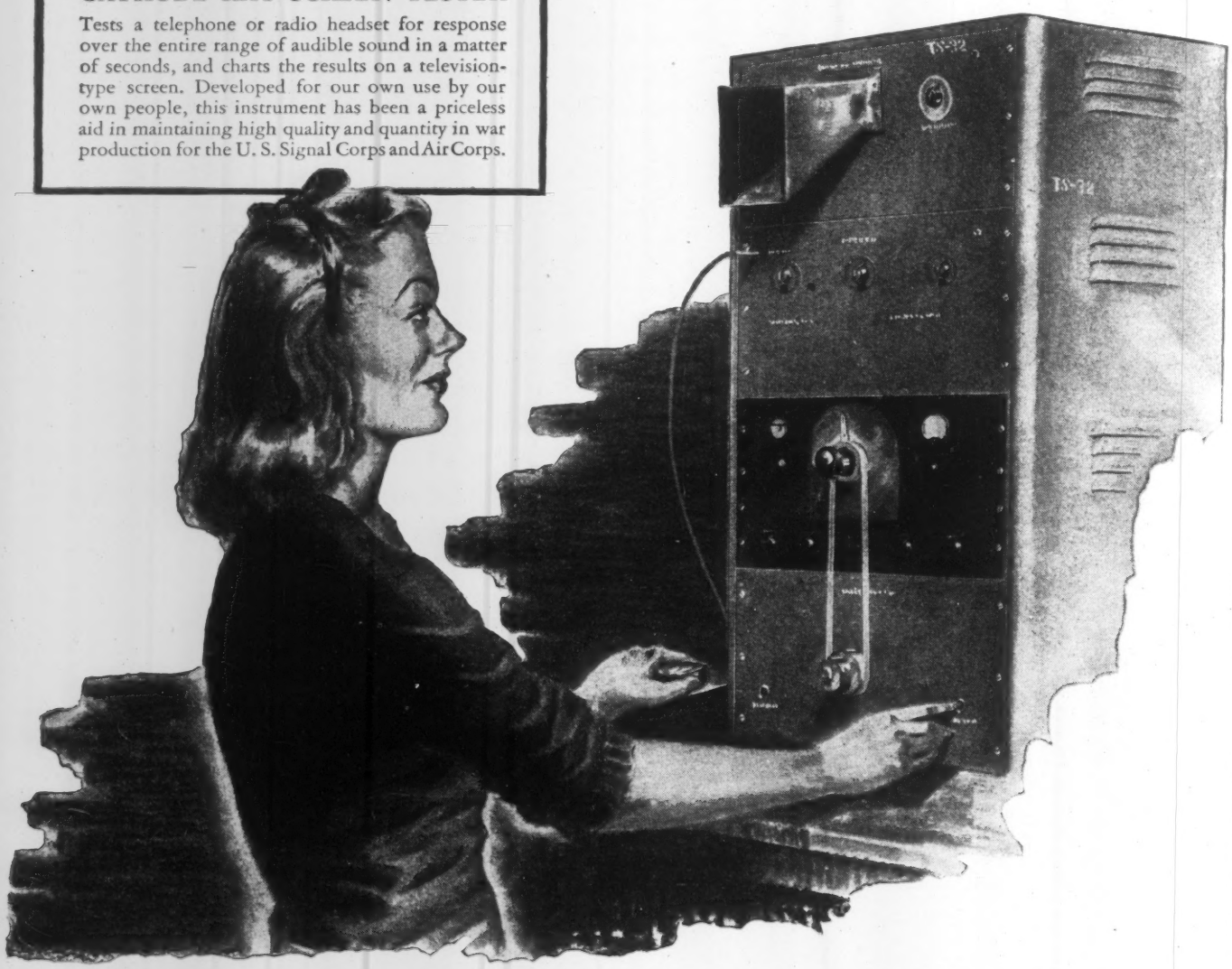
SPECIAL tools, ingenious manufacturing devices, and elaborate test equipment which makes delicate measurements almost as easy as telling the time . . . these things seem to interest our visitors particularly. We are always proud to point out that most of these aids to swift, precise production were developed by our own men and women.

There's a world of skill and experience at Connecticut Telephone & Electric Division . . born of nearly fifty years of practice and progress. This know-how isn't confined to our engineering departments, either. Some of our most useful suggestions come straight from the production lines.

Purchasers of C. T. & E. products benefit from this skill and ingenuity . . . in better, more advanced devices, produced faster, for less.

CATHODE RAY SCREEN TESTER

Tests a telephone or radio headset for response over the entire range of audible sound in a matter of seconds, and charts the results on a television-type screen. Developed for our own use by our own people, this instrument has been a priceless aid in maintaining high quality and quantity in war production for the U. S. Signal Corps and Air Corps.

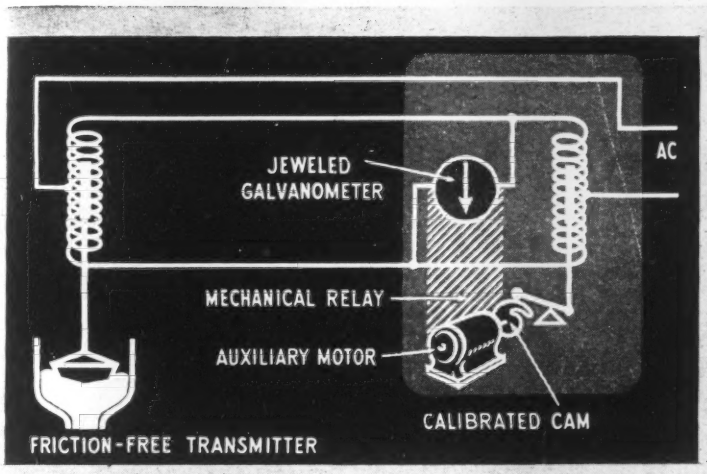


ARMY E NAVY

GAI

CONNECTICUT TELEPHONE & ELECTRIC DIVISION
GREAT AMERICAN INDUSTRIES, INC. • MERIDEN, CONN.

TELEPHONIC SYSTEMS • SIGNALLING EQUIPMENT • ELECTRONIC DEVICES • ELECTRICAL EQUIPMENT
HOSPITAL AND SCHOOL COMMUNICATIONS AND SIGNALLING SYSTEMS • IGNITION SYSTEMS

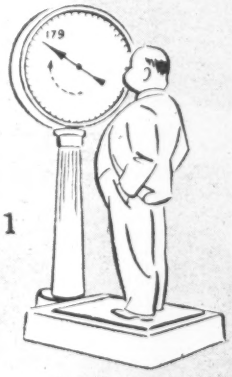


In the Cochrane Flow Meter, the Null or Zero Balance principle is employed, balancing the unknown quantity by adjusting a known quantity of the same kind. A highly sensitive detector is used to determine the point of balance. A friction-free transmitter serves as a pilot for an external motor drive. The motor restores the bridge to balance and operates recording pen, indicating pointer, and integrator. The measuring circuit is relieved of all work.

—

NO HYSTERESIS . . . NO FRICTION LAG

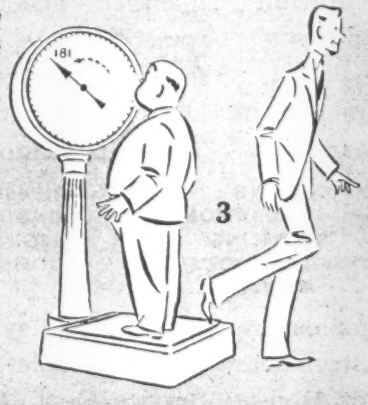
What is Hysteresis?



1. *Let's say you actually weigh 180 pounds. When you step on the platform spring scales in the drug store, the pointer goes up fast until it approaches 180. The movement becomes slower and slower, the pointer finally stops at 179.*

2. *Now you try it again but this time another man steps on the scales with you, your combined weight registering 300.*

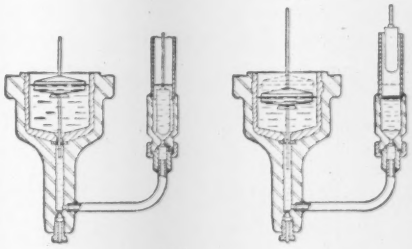
3. *Then your friend steps off and the pointer comes down from 300 and gives your weight now as 181.*



The discrepancy results from approaching the balance point from opposite directions with a deflectional system. Exact balance is never attained. "Hysteresis" is the word for it.

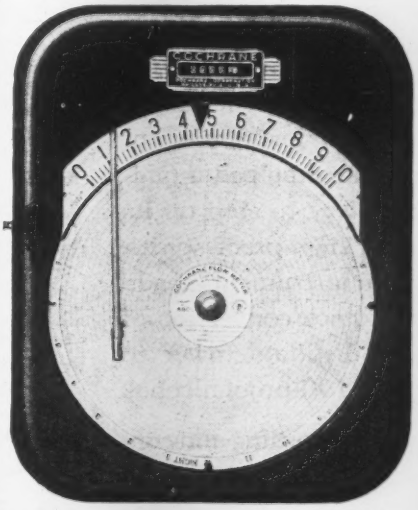
Accuracy Quickly Checked

In less than five minutes, a Cochrane Flow Meter, from mercury level clear through to the pen record can be verified as to accuracy. The check is made at 20 per cent of meter capacity after the meter has been checked at zero by means of the simple zero adjusting screw in the receiver.



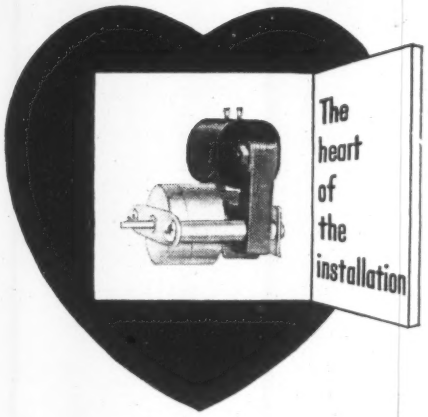
As shown above, when the calibrating rod of the transmitter is raised, the mercury surface is lowered, thus causing the float to assume a position corresponding exactly to a 20 per cent rate of flow. Compare this easy method with the clumsy, inconvenient water column method.

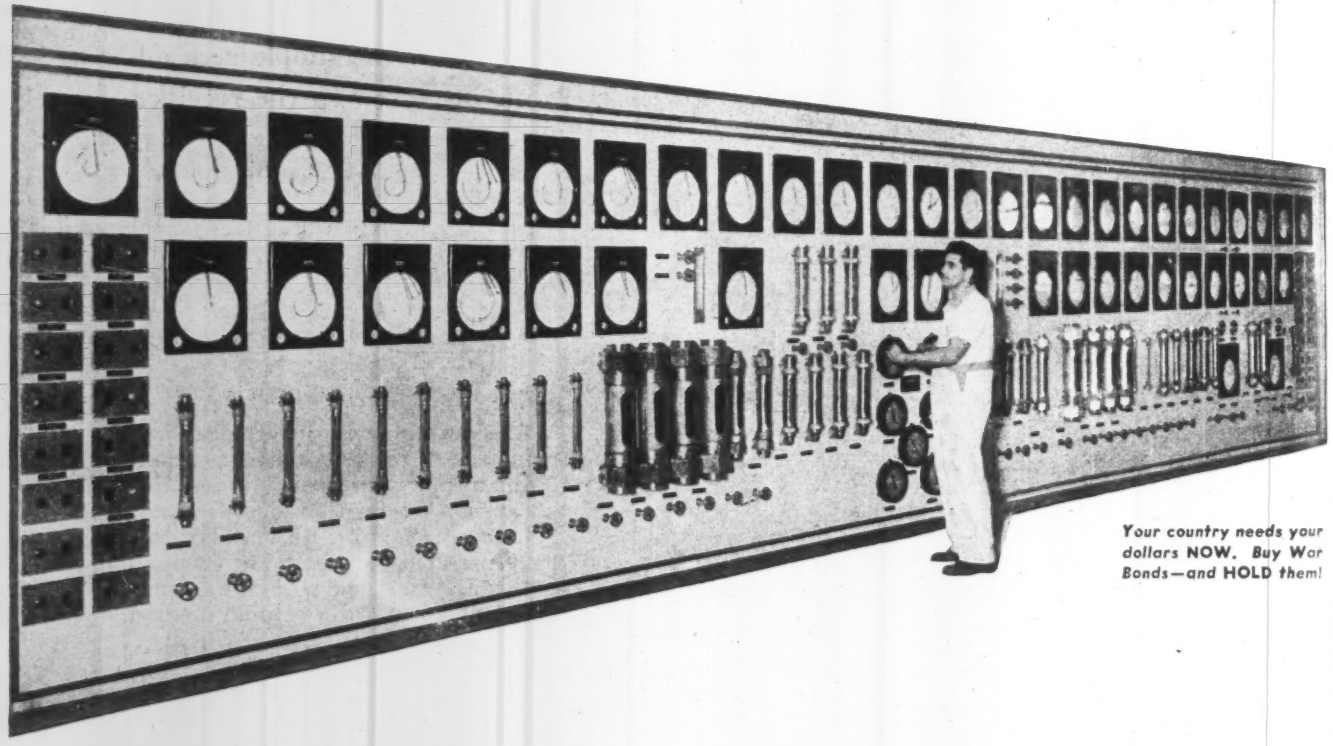
COCHRANE CORPORATION
3120 N. 17th St., Philadelphia 32, Pa.



COCHRANE FLOW METERS

SPEEDING SPIRITS FOR WAR USE WITH TELECHRON MOTORS





Your country needs your dollars **NOW.** *Buy War Bonds—and* **HOLD** *them!*

WHEN war called for greatly increased supplies of industrial alcohol, installation of this control panel helped a midwestern distillery to step up its production of high-proof spirits. These control instruments made possible the quick conversion of a low-proof distillate tower to production of 190-proof alcohol.

Each of the recording and controlling instruments is driven by a *synchronous, self-starting Telechron motor.* They record and control the feed to the tower, the steam used in distillation, temperature of the cooling water, and the vacuum in the tower. Their smooth, constant speed keeps the distillation process at peak efficiency—around the clock.

Telechron motors are available in sizes from 12 to 250 volts for all commercial frequencies—and from 1 to 1800 rpm. Accurate, dependable and flexible, they are used in all kinds of industrial operations. Their applications include:

TIMING
CONTROLLING
METERING
RECORDING
SWITCHING
CYCLING OPERATIONS
SIGNALING
FIXED PROCESS CONTROLLING
MEASURING
GAGING
REGULATION
COMMUNICATIONS

Our more than 25 years' experience in making synchronous, self-starting motors for instrumentation is available to you for the asking. Just write Motor Advisory Service, Dept. A.

Telechron

REG. U. S. PAT. OFF.

WARREN TELECHRON COMPANY • ASHLAND, MASSACHUSETTS

MAKERS OF TELECHRON ELECTRIC CLOCKS AND SYNCHRONOUS ELECTRIC MOTORS

Vinylite

TRADE-MARK

PRECISION
FOR THE RULE OF THUMB

Rule of thumb was the old "by guess and by gosh" method of measurement and calculation. Today we get more trustworthy answers with precision instruments. And thumbs are now *really* on the job, sliding the moving parts and twirling the dials of instruments made of VINYLITE plastic rigid sheets. Aerial navigators, artillerymen, and engineers depend on them for the quick solution of vital problems.

Drafting, measuring, and computing instruments made of VINYLITE plastic rigid sheets remain dimensionally stable within a wide temperature range and under all atmospheric conditions. In addition, these sheets are highly resistant to most chemicals and to oxidation. With light weight they combine great tensile and impact strength—and abrasion resistance that assures a long useful life. They're available in several standard thicknesses—in a broad choice of colors, transparent, translucent, and opaque. Importantly, too, VINYLITE plastic rigid sheets can be machined and formed into complicated three-dimensional shapes on your standard metal-working equipment. And they readily take and hold close-register, multi-color printing.

Booklet VK-35 gives full information about VINYLITE plastic rigid sheets—shows the way to product improvement and production economies. A copy is yours upon request.

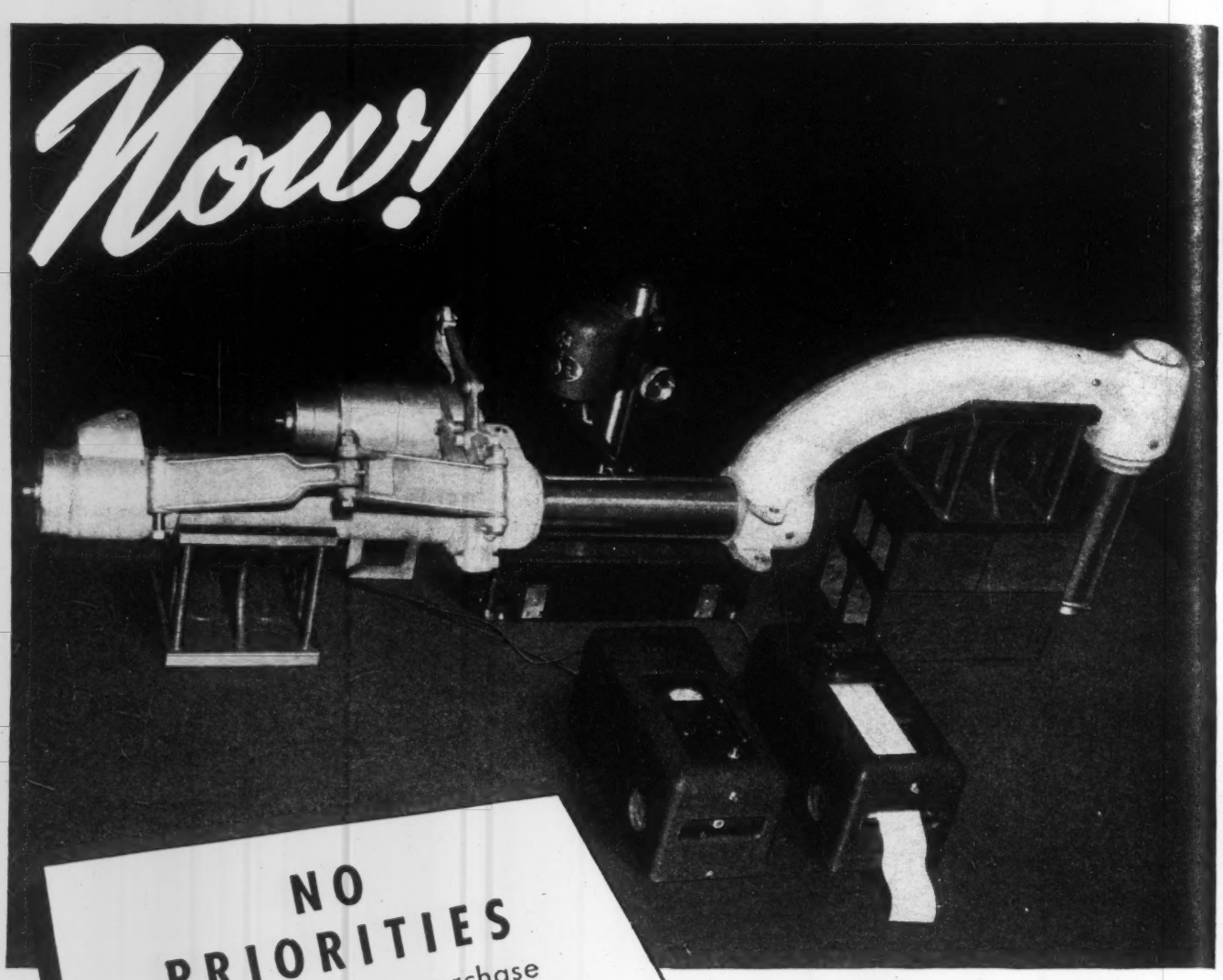
BAKELITE CORPORATION
Unit of
Union Carbide and Carbon Corporation

UCC

30 EAST 42ND ST., NEW YORK 17, N. Y.

Plastics

Now!



At the Willow Run Bomber Plant of the Ford Motor Company, the Brush Surface Analyzer determines the smoothness of oleo strut pistons.

NO PRIORITIES

are necessary to purchase a Brush Surface Analyzer . . . Approximately two week delivery on unrated orders . . .

THE BRUSH SURFACE ANALYZER

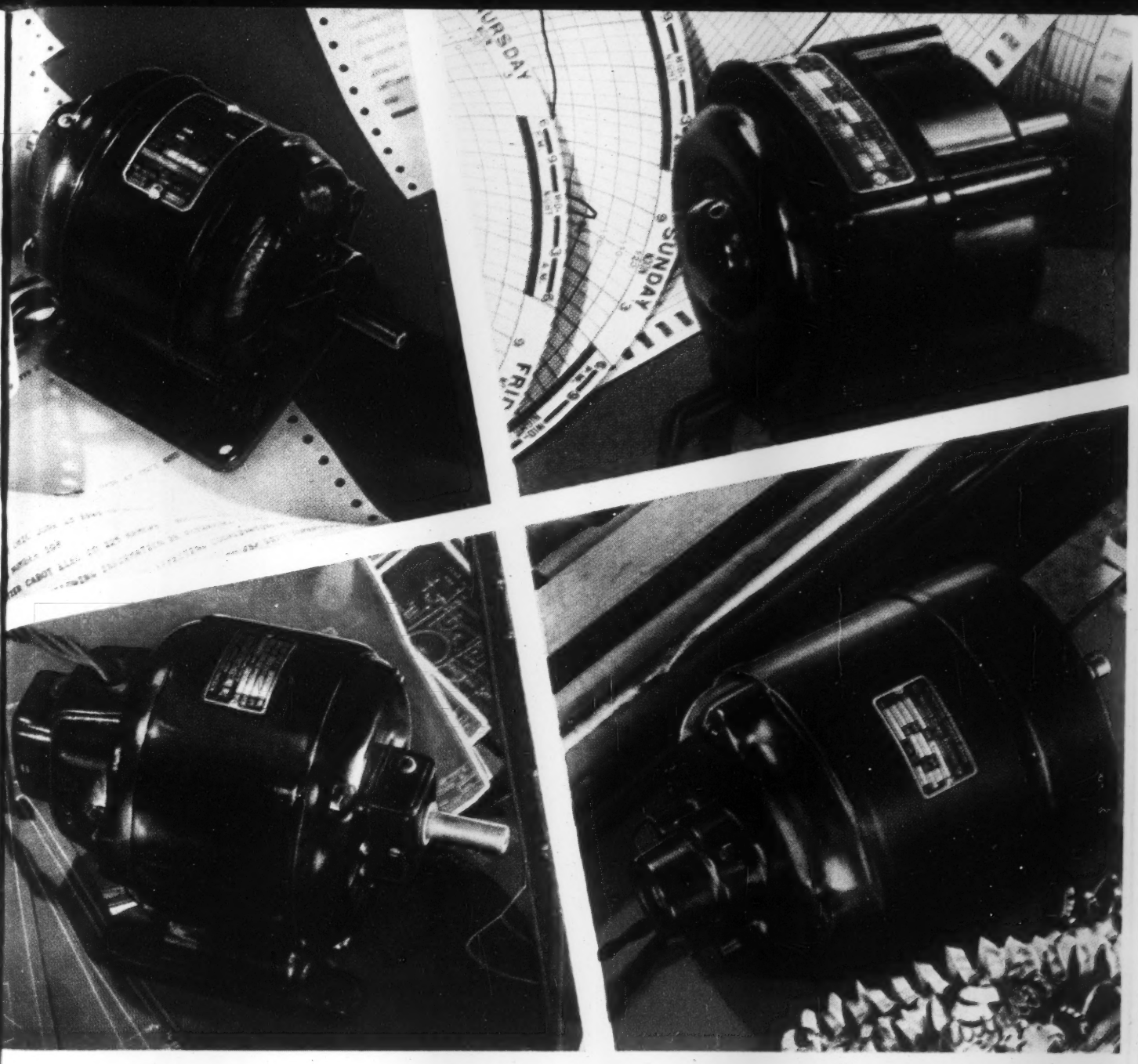
measures and records the irregularities as shallow as a millionth of an inch on steel . . glass . . plastics . . plated and painted surfaces.

Ask for a demonstration at your plant.

An Illustrated brochure, SURFACE FINISH—.000001", sent on request.

THE BRUSH DEVELOPMENT COMPANY

3413 PERKINS AVENUE • CLEVELAND 14, OHIO



Special Motor Application . . . *Improves Machine Performance . . . Meets Mechanical Specifications*

Although standard off-the-shelf motors can often be used in a product, experience proves that when the electric motor is specially designed for a specific application, the machine operates more efficiently and economically with less maintenance.

For over 50 years Holtzer-Cabot has concentrated its facilities in the design and application of special motors, such as those illustrated above, to meet specific design and performance requirements of such products as machine tools, instruments, business machines and aircraft. And although today, military requirements get first call on all of Holtzer-Cabot's motor production, our motor development engineers are available for consultation on your postwar fractional H. P. motor requirements with you. There is no obligation, of course.

HOLTZER-CABOT

Division of First Industrial Corporation

Designers and Builders of Special Fractional HP Motors and Electrical Apparatus

125 AMORY STREET, BOSTON 19, MASS. • NEW YORK, N. Y. • CHICAGO, ILL. • PHILADELPHIA, PA.

RAYTHEON VOLTAGE STABILIZERS

CONTROL VARYING LINE VOLTAGES

TO 115 VOLTS ± ½%

Ordinary A.C. line voltages as taken from supply mains often vary as much as from 95 to 130 volts. This impairs the precision operation of electrical equipment.

A Raytheon Voltage Stabilizer, built into new products or incorporated into equipment already in use, overcomes the disadvantage of fluctuating voltages by providing an accurately controlled source of power to ± ½%.

Here's what a Raytheon Stabilizer does—stabilizes varying input voltage from 95 to 130 volts to 115 volts ± ½% within 2 cycles.

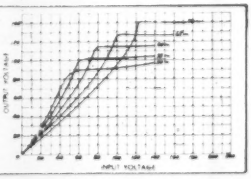
Raytheon Voltage Stabilizers are entirely automatic. They require no adjustments or repeated maintenance. No moving parts assure long life. Write for bulletin DL 48–537.

EFFECT OF VARIABLE FREQUENCY

Since partial resonance is a requisite design feature, these devices are sensitive to frequency changes. The output voltage will vary in the same direction and 1.4 times the percentage change in frequency, over a range of 5% of the normal frequency.

Stabilization, however, will be within ± ½% at the output voltage which is established by the frequency.

TYPE VR 2
INPUT VS OUTPUT VOLTAGE
FOR VARIOUS FREQUENCIES



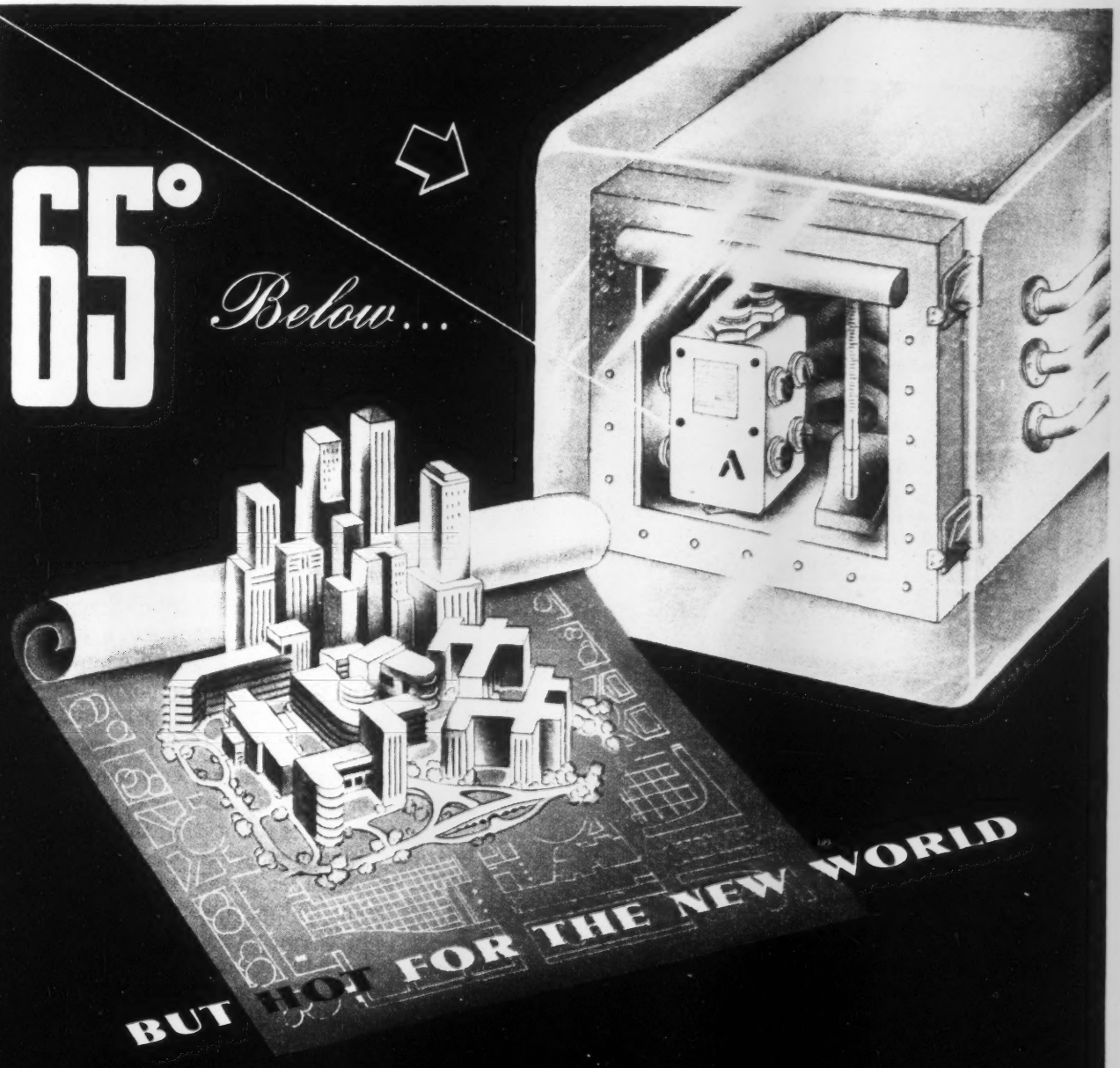
Tune in the Raytheon radio program: "MEET YOUR NAVY," every Saturday night on the Blue Network. Consult your local newspaper for time and station

RAYTHEON
MANUFACTURING COMPANY
Electrical Equipment Division
190 WILLOW STREET, WALTHAM, MASS.

The coveted Army-Navy "E," for Excellence in the manufacture of war equipment and tubes, flies over all four Raytheon Plants where over 16,000 men and women are producing for VICTORY.

Devoted to research and manufacture of complete electronic equipment; receiving, transmitting and hearing aid tubes; transformers; and voltage stabilizers.

65° *Below...*



. . . In Kenyon's High Altitude Chamber, Relief Valves—a delicate and vital part for American warplanes—are subjected to cold tests as severe as 65 below.

. . . But Kenyon is far more than a testing laboratory—it is an organization of skilled workmen and engineers who ***design, create, test*** and ***produce*** precision parts to meet a specific manufacturing need *even if such a part has never been made before.*

. . .

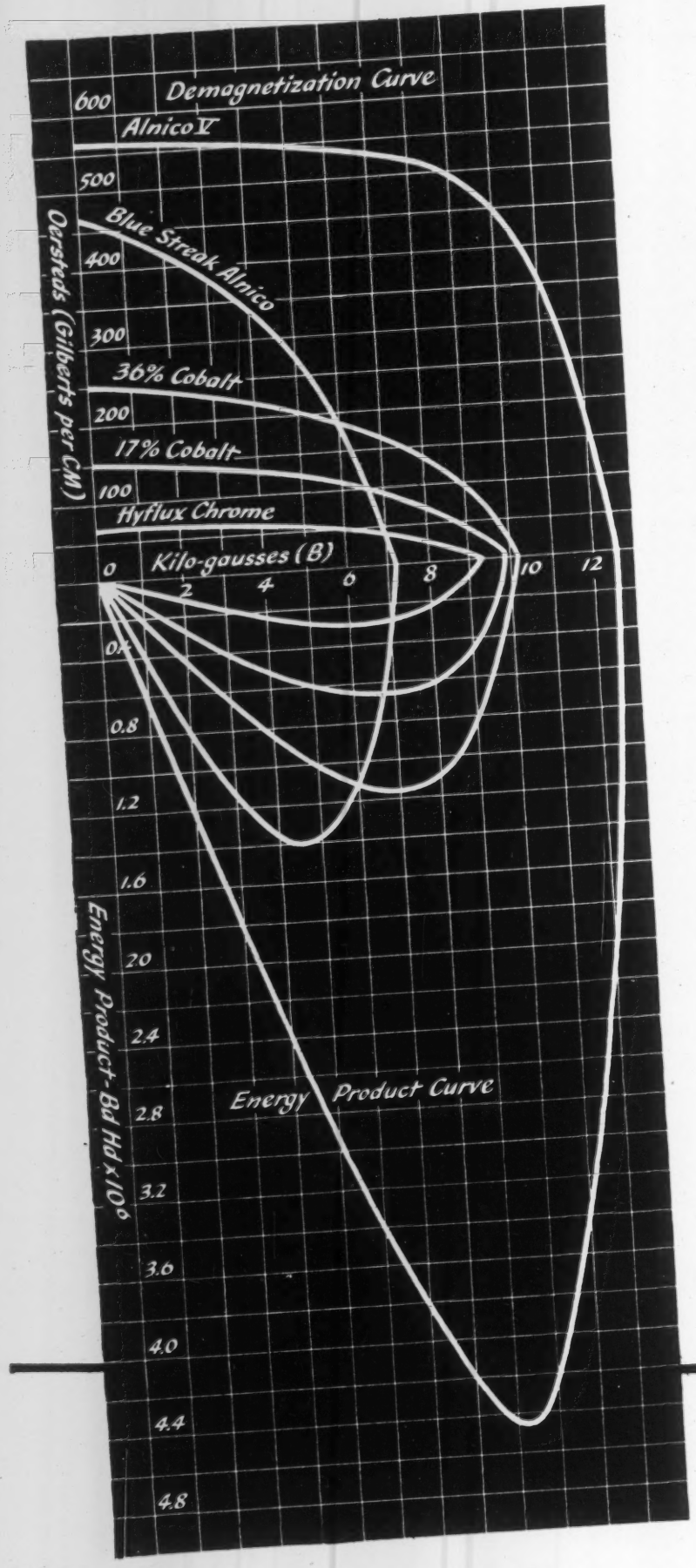
. . . Your part may require an even more exacting test than do aviation Relief Valves.

. . . But no matter if your engineering problem is large or small, simple or complex, Kenyon offers you ***complete*** precision engineering service—from the ***basic design*** to the ***completed product***—whether in war or in the years ahead

KENYON
INSTRUMENT CO., INC.
HUNTINGTON, L. I., N. Y.

CUSTOM DESIGNERS OF PRECISION PARTS FOR AMERICAN INDUSTRY

PERMANENT MAGNETS MAY DO IT BETTER



Magnetic Material Improvements

Metallurgical research is constantly expanding the productivity of permanent magnets, through the discovery of new magnetic materials and alloys. The permanent magnet of today is capable of *three times* the output of magnetic energy of that of 1939, and *nine times* that of 1917.

The proper utilization of materials in permanent magnets produces a specified ability to maintain the required magnetic field after the magnet has been magnetized—often despite severe external demagnetizing forces.

The development of permanent magnet materials of higher coercive force opens up many new applications of larger scope. Our research is facilitating these applications by employing an experience of more than a third of a century in the exclusive manufacture of permanent magnets. Our engineers are available for consultation to help solve your problems in the use of permanent magnets. Write for specific information; ask for free copy of pamphlet *"Permanent Magnets Have Four Major Jobs."*

★ **THE INDIANA STEEL PRODUCTS COMPANY** ★

6 NORTH MICHIGAN AVENUE • CHICAGO 2, ILLINOIS

★ *A Star was Added* *in January, 1945*

Specialists in Permanent Magnets Since 1910

COPYRIGHT 1945, THE INDIANA STEEL PRODUCTS COMPANY

meets special applications

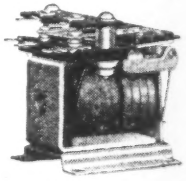
saves time . . . saves tooling . . . speeds delivery!

If your application requires a specially designed relay Guardian engineers can be of great help to you. But, as a result of their wide experience in designing "specials" they have evolved a standard design so flexible that it is now specified in numerous applications that would ordinarily require a specially designed unit. Perhaps you can use it in your "special" application . . . with a saving in money and delivery time. This unusually flexible relay is the SERIES 345. Its chief features are the large coil winding area, numerous contact combinations, the non-binding pin type armature hinge pin, its resistance to shock and vibration, and an ability to operate in extremes of temperature. It is now being used in aircraft, radio, and other exacting applications to insure dependable performance.

STANDARD SERIES 345—The ample coil winding area of the SERIES 345 gives you a wide range of windings for various voltages and currents. Coil winding area is approximately .75 cubic inches. Average power required is 3.56 watts with three pole, double throw contacts of 12½ amp. capacity. Coils are available for either A.C. or D.C. operation.

The maximum switch capacity of the Standard Series 345 is three pole, double throw. Contacts are rated at 12½ amperes at 110 volts, 60 cycles, non-inductive A.C. Moving contacts are attached to but insulated from the armature by a bakelite plate. Terminals are solder lugs. Weight is 6½ ounces.

VARIATIONS OF THE SERIES 345 RELAY



TIME DELAY

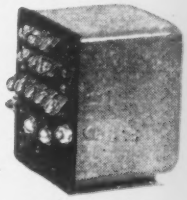
WINDING—Multi-wound coils are available for operation on two or more circuits. Or coil may be wound to operate on the discharge of a 3 mfd. condenser.

CONTACTS—Normal switch capacity is three pole, double throw; maximum switch capacity may be up to six pole double throw with 12½ amp. contacts, or any variation of contact combinations within this range, including the operation of contacts in sequence. The flexibility of the contact springs may be increased through the use of coil spring rivets.

TIME DELAY—On D.C. coils a time delay of 0.25 seconds on release or 0.06 second on attract may be achieved through the use of copper slugs which require these time intervals for saturation or de-energizing depending on whether they are used on the heel or head of the coil.

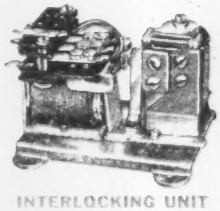
DUST COVER—For applications where this relay may be subject to injury or in atmosphere where dust may be present in sufficient quantity to impede operation, the SERIES 345 may be equipped with a metal dustproof cover.

SCREW TERMINALS—Screw type terminals are optional for applications where terminals must be disconnected occasionally or where solder lug terminals are not otherwise practical.



DUST COVER

INTERLOCKING—The SERIES 345 may be used in combination with various coils to achieve a mechanical interlock. One of the most recent developments is the use of the SERIES 345 in an overload application. Excessive current energizes the SERIES 345 coil. The armature is then mechanically locked in the energized position by an arm attached to a Series 405 coil and is held in the locked position until the Series 405 coil is energized by a push-button arrangement. If current through the Series 345 is still excessive, relay remains in locked position even though released by push-button control.



INTERLOCKING UNIT

SERIES 345 RELAY DATA

Normal Volts	Minimum Volts	Normal M.A.	Minimum M.A.	Coil Resist.	Normal Wattage
6	4.8	600	480	10	3.56
12	9.8	300	245	40	3.56
24	18	148	111	162	3.56
32	25.6	112	89	287	3 56
115	92	31	25	3720	3.56

Minimum operating wattage.....2.3

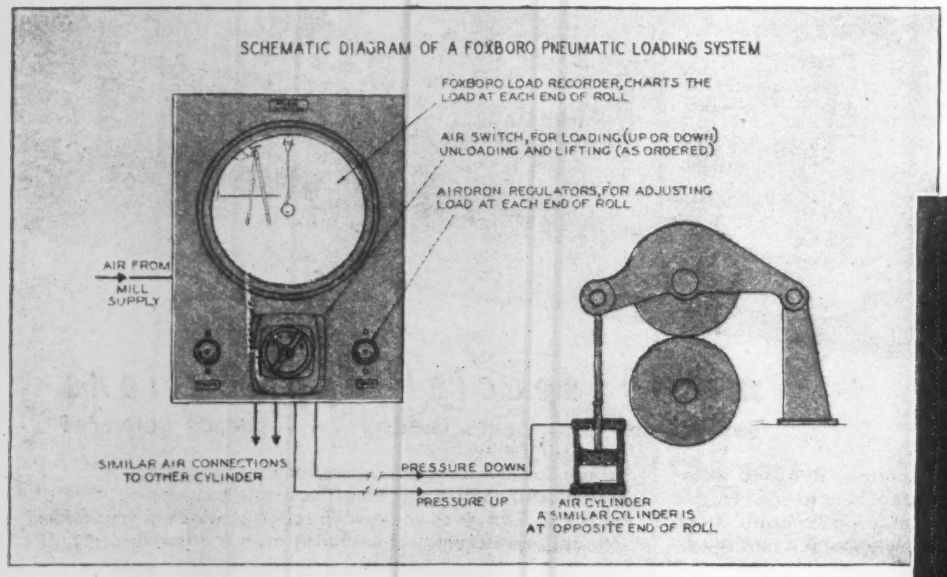
If you will write us about your relay problems our engineers will be glad to make recommendations which may save you time and money. Should you desire a quotation, please mention quantity.

GUARDIAN ELECTRIC

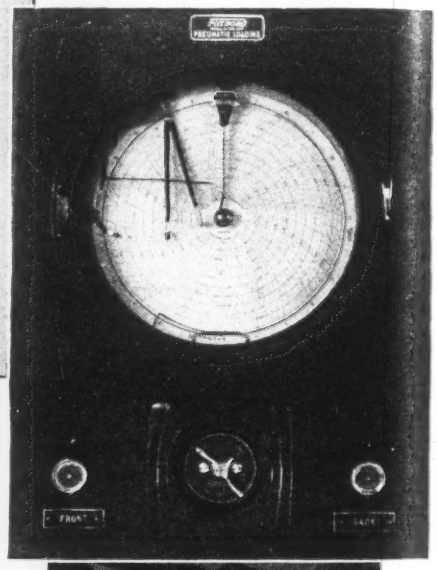
1638-C W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

BIGGEST ADVANCE EVER MADE in Applying Roll Pressure!


SCHEMATIC DIAGRAM OF A FOXBORO PNEUMATIC LOADING SYSTEM
FOXBORO LOAD RECORDER, CHARTS THE LOAD AT EACH END OF ROLL
AIR SWITCH, FOR LOADING (UP OR DOWN) UNLOADING AND LIFTING (AS ORDERED)
AIRDRON REGULATORS, FOR ADJUSTING LOAD AT EACH END OF ROLL
AIR FROM MILL SUPPLY
SIMILAR AIR CONNECTIONS TO OTHER CYLINDER
PRESSURE DOWN
PRESSURE UP
AIR CYLINDER
A SIMILAR CYLINDER IS AT OPPOSITE END OF ROLL

Schematic drawing (left) shows operating principle of Foxboro Pneumatic Loading. Below is complete control panel with Pressure Recorder, Dual Air Switch and pressure-adjusting Airdron Regulators.



Foxboro Pneumatic Loading gives calibrated, "cushioned" pressure with fingertip control

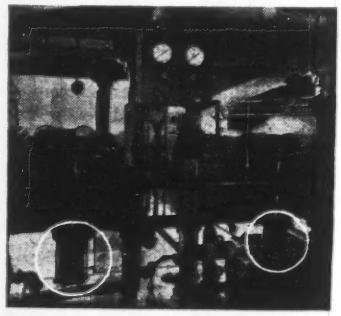
A turn of two knobs . . . that's all there is to loading any roll equipped with Foxboro Pneumatic Loading!

Pressures are maintained automatically and precisely. The smooth, cushioned action of the air cylinders compensates for variations in material thickness and for any out-of-roundness of the rolls. This action also snubs bouncing — often permits higher roll speed. The special air switch gives instant unloading and reloading; if desired, it also provides reverse pressure for lifting the roll out of contact. Roll ends are usually loaded independently to permit compensation for machine conditions, but the cylinders may be manifolded to work together.

For many press-roll operations, Foxboro Pneumatic Loading offers various radical improvements, such as greater overall extraction and closer control of final moisture content, thorough saturation and uniform removal of excess liquid. Corresponding gains in quality and uniformity are often achieved in finishing processes, as well.

Phone or write the nearest Foxboro Office for a copy of detailed Bulletin B306. If desired, a Foxboro engineer will gladly call to discuss how this unique loading can improve your roll operations. **The Foxboro Company, 46 Neponset Ave., Foxboro, Mass., U. S. A.** Branches in principal cities.

Foxboro Pneumatic Loading has brought new efficiency to paper mill operations.



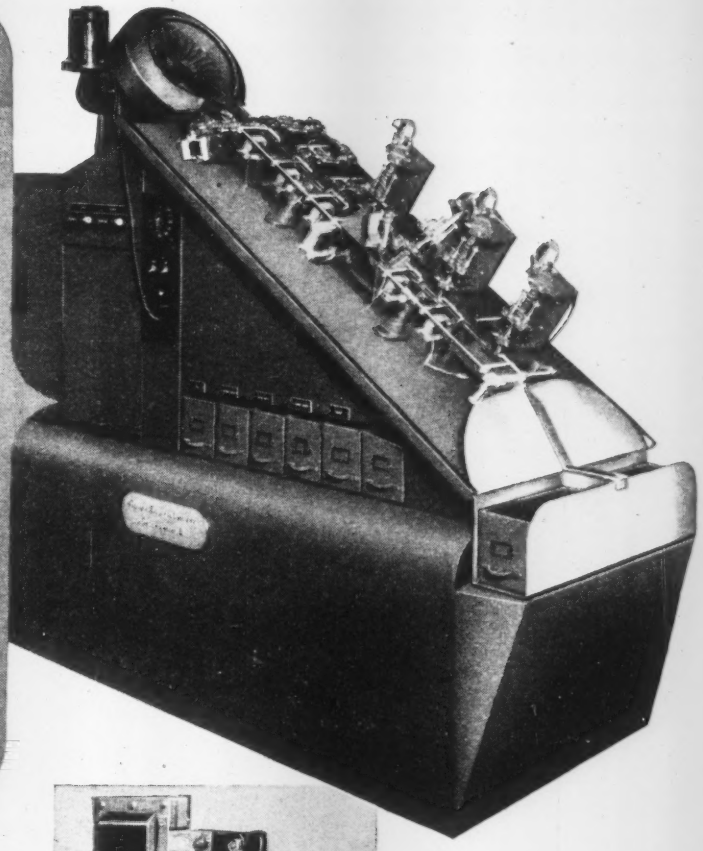
Also widely used today on textile operations such as slashing and dye-padding.

FOXBORO REG. U. S. PAT. OFF. **PNEUMATIC LOADING**

86 Pieces Gaged Per Minute

EACH CHECKED FOR 7 DIMENSIONS

Thanks to MICRO SWITCH

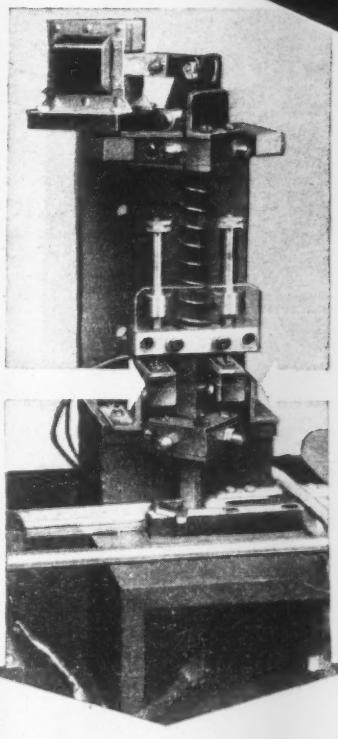


Automatic checking of small parts to assure that they are within allowable tolerances is accomplished by this "Gage-O-Matic" precision gaging machine through the use of Micro Switch products.

Built by the General Control Company for the use of Hamilton Standard Propellers, the "Gage-O-Matic" permits high speed checking of seven accurate dimensions at the rate of 86 pieces per minute.

This is accomplished by pairs of plastic enclosed switches which monitor each gaging operation. They are actuated by micrometer heads mounted on a sliding bar. If the part being tested is in tolerance, *one* switch is actuated . . . if under tolerance, *both* are actuated . . . if over tolerance, neither is actuated.

If the part is over or under tolerance, it drops through a tube into the proper rejection drawer, automatically segregating rejected parts for their particular defect.

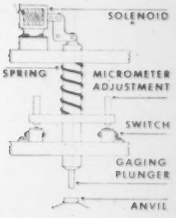


1,001 Jobs For Micro Switch Products

Sensitive reaction of the tiny basic switch to slight operating force makes it a natural component for 1,001 jobs in industry as the electrical control for gages and instruments. Among their important uses are: on automatic weighing machines, position indicators, float alarms, temperature controls, counting mechanisms and many other electrical and electronic devices.

Designers of electrically controlled instruments and gages should be thoroughly familiar with the many advantages of the dependable, compact Micro Switch designed snap-action switch. Write today for Handbook-Catalog No. 60, which gives complete details on electrical characteristics, housings and actuators.

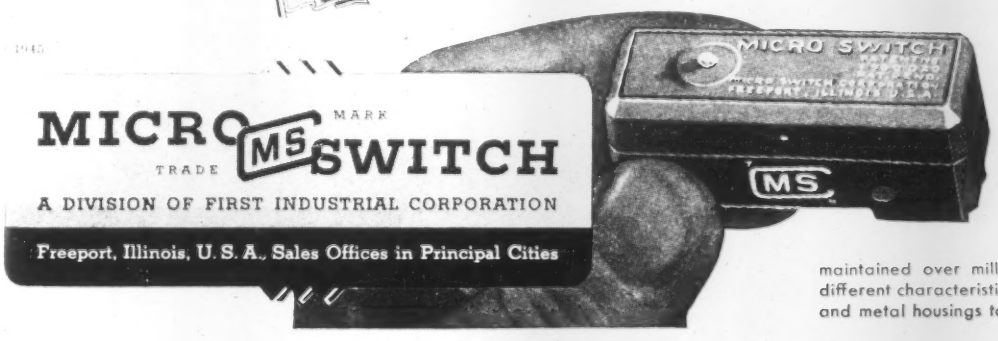
Here's How it Works



The small parts are fed through a chute by a rotating hopper. As the part slides down the chute, it is stopped at different intervals by solenoid controlled levers. The part is positioned between the gaging plunger and anvil, then the solenoid on the gaging head is released. The spring drives the gaging plunger assembly down and in contact with the part.

The gaging assembly is then pulled up by the solenoid and the part, if acceptable, is permitted to move to the next stage.

LET'S ALL BACK THE ATTACK *BUY EXTRA WAR BONDS*



This is the basic switch—a thumb-size, feather-light, plastic enclosed, precision, snap-action switch, Underwriters' listed and rated at 1200 V. A., at 125 to 460 volts a-c. Capacity on d-c depends on load characteristics. Accurate reproducibility of performance is maintained over millions of operations. Basic switches of different characteristics are combined with various actuators and metal housings to meet a wide range of requirements.

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TRADE MARK

A DIVISION OF FIRST INDUSTRIAL CORPORATION

Freeport, Illinois, U. S. A., Sales Offices in Principal Cities

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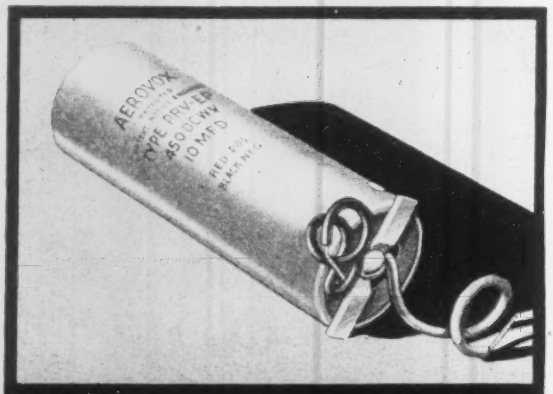
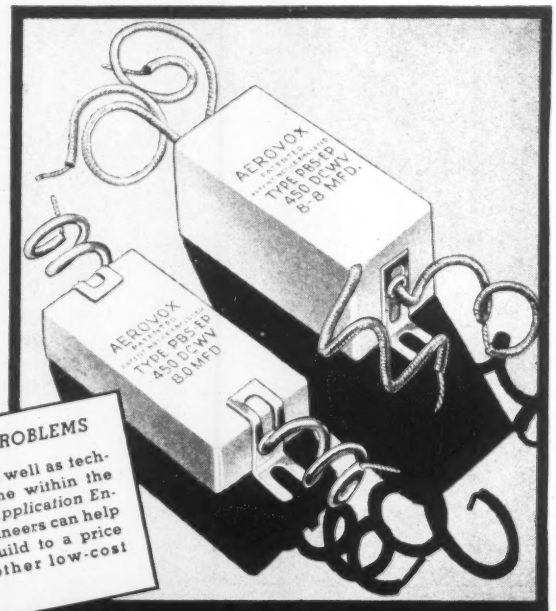
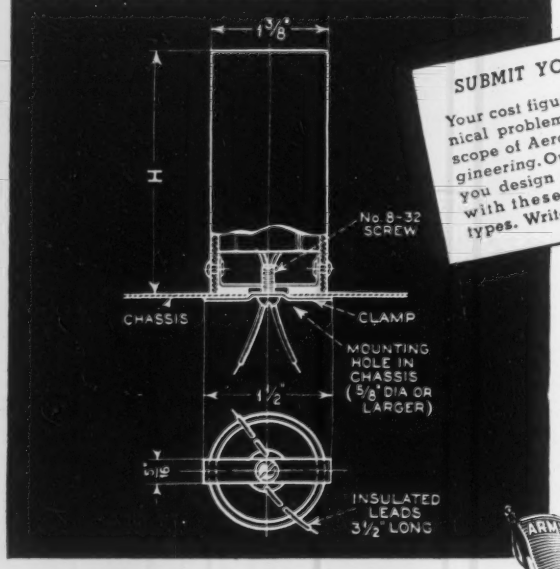
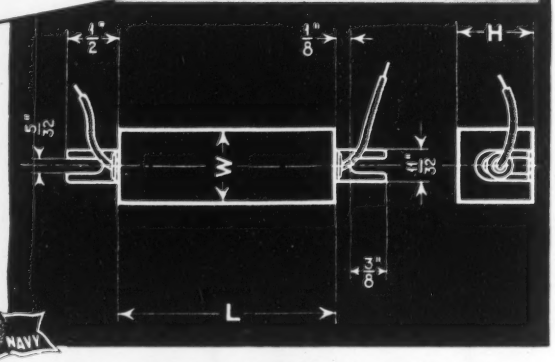






SUBMIT YOUR PROBLEMS

Your cost figures, as well as technical problems, come within the scope of Aerovox Application Engineering. Our engineers can help you design and build to a price with these and other low-cost types. Write us.



CLAMP-MOUNTING ELECTROLYTICS

● **PRICE** with inbuilt *Aerovox Quality*—that's the prime objective of the ingenious Type PRV one-hole-mounting paper-cased electrolytic. • Wax sealed. Impregnated cardboard-tube container. Suitable for commercial and other applications where extreme operating conditions are not encountered and metal-can types are not essential. • Note ingenious clamp and center-screw mounting means. This type can take the place of various other vertical-mounting electrolytics such as twist-prong, spade-lug, screw-base, etc. • Normally with etched foil. Also available in plain foil. High-purity aluminum elements throughout. Positive and negative lead for each section. 450 and 600 v. D.C.W. 4 to 40 mfd.; 8-8 to 20-20 mfd. 1-3/8" dia.; 3 to 4-3/4" high.

CARDBOARD-CASE ELECTROLYTICS

● **PRICE** with inbuilt *Aerovox Quality*—that's the prime objective of this popular Type PBS rectangular cardboard-case dry electrolytic. • Sections housed in sturdy cardboard containers. Patented Aerovox Adjustimount or swivel metal flange permits mounting flatwise or on narrow side according to space limitations. Also, PBS units may be stacked and held together by overlapping metal flange and soldering securely. • Normally with etched foil. Plain foil also available. High-purity aluminum elements throughout. Made in single and multiple sections. Separate sections with positive and negative leads for each section. • 450 and 600 v. D.C.W. 4 to 16 mfd.; 8-8, 8-16 and 8-8-8 mfd. Dimensions: *L*, 2-7/16 to 3-3/16"; *W*, 3/4 to 1-1/2"; *H*, 1/2 to 1-7/16". A good general-purpose electrolytic for normal service.

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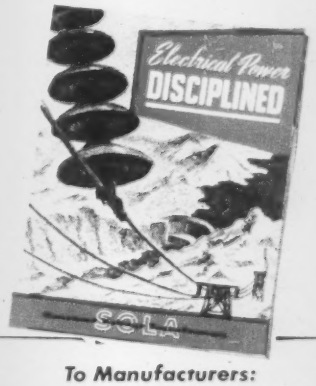
That SOLA CONSTANT VOLTAGE TRANSFORMER, built into our equipment, will eliminate a majority of our most critical field problems

Every sales manager of electrical equipment knows the number of expensive service calls, the number of complaints of sub-standard performance that can be traced directly to unstable line voltages.

A majority of them can be avoided by simply specifying "SOLA Constant Voltage Transformers" while the equipment is still on the drafting board.

The inclusion of SOLA Constant Voltage Transformers in the basic design can generally be accomplished at an actual saving in cost. Their use frequently eliminates the need for other component parts whose only function is to provide superfluous manual control over the equipment.

SOLA Constant Voltage Transformers require no supervision. They have no moving parts or delicate networks to get out of order. They react instantly and automatically to line voltage disturbances, correct fluctuations as great as 30% to the safe operating limits called for on the label. They protect both themselves and the equipment against short circuit.



To Manufacturers:
Built-in voltage control guarantees the voltage called for on your label. Consult our engineers on details of design specifications.
Ask for Bulletin GCV-102

SOLA Constant Voltage Transformers

Transformers for: Constant Voltage • Cold Cathode Lighting • Mercury Lamps • Series Lighting • Fluorescent Lighting • X-Ray Equipment • Luminous Tube Signs Oil Burner Ignition • Radio • Power • Controls • Signal Systems • Door Bells and Chimes • etc. **SOLA ELECTRIC CO., 2525 Clybourn Ave., Chicago 14, Ill.**

OHMITE *Rheostats*

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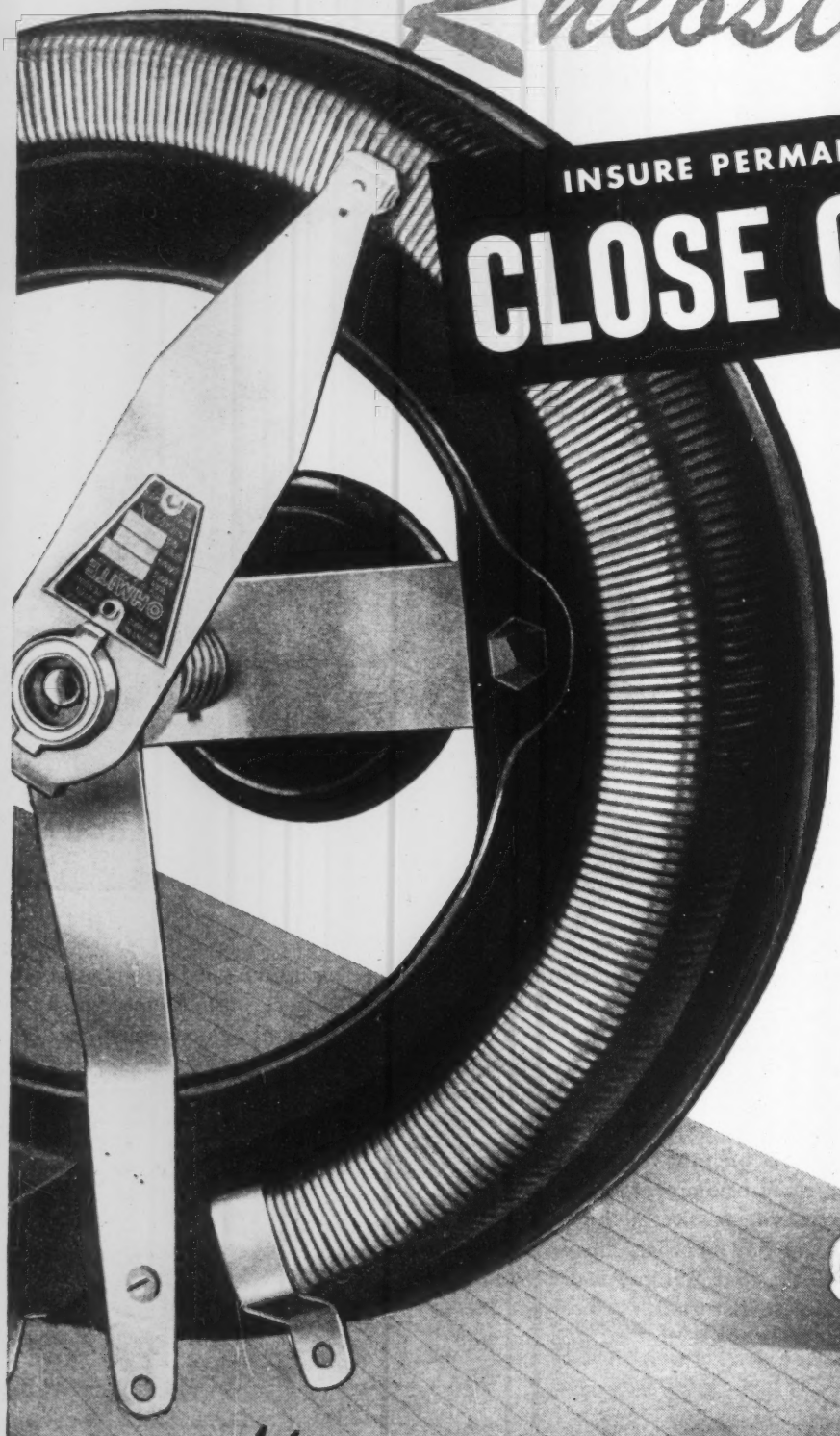
CLOSE CONTROL



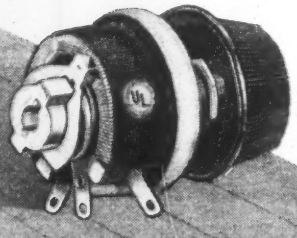
10 Wattage Sizes

. . . in a variety of types to meet every need

There's an Ohmite Rheostat to assure the best unit for each control need . . . from the 1000 watt, 12″ diameter, Model "U" to the 25 watt, 1 9/16″ diameter, Model "H". Made in single or tandem units, with uniform or tapered windings, in stock or special resistance values. And large or small—each Ohmite Rheostat is designed to give smooth, close control—long life—and trouble-free service. In Resistance Control, Ohmite Experience Makes a Difference.

Write on company letterhead for Catalog and Engineering Manual No. 40.

OHMITE MANUFACTURING CO.
4886 Flournoy St., Chicago 44



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RHEOSTATS • RESISTORS • TAP SWITCHES

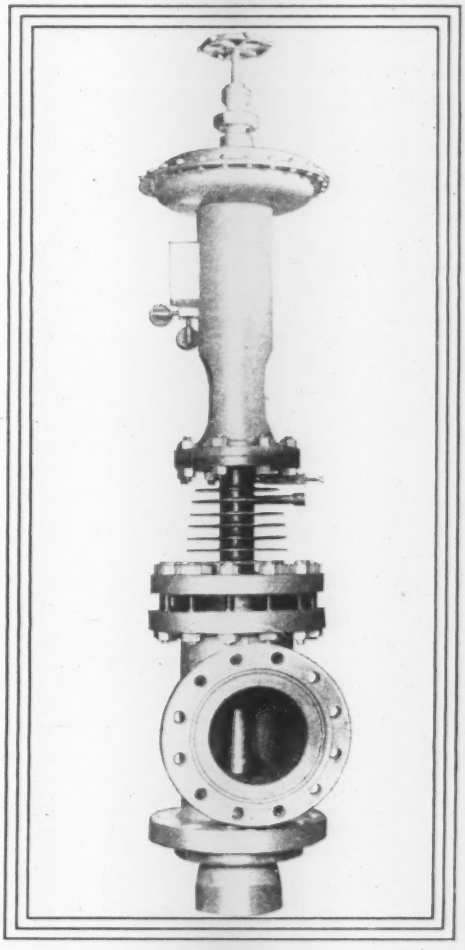
AUTOMATIC CONTROL EQUIPMENT

ENGINEERED DESIGN BY **HAMMEL-DAHL**

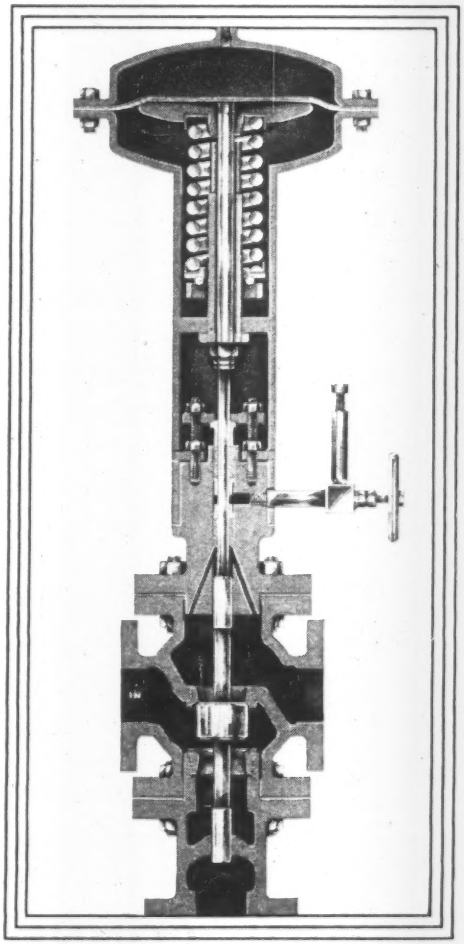
Check these FEATURES

VENTURI-FLOW DIAPHRAGM CONTROL VALVES

The Hammel-Dahl 03-000 Series Venturi-Flow type valve is available only in the angle type construction. Designed primarily for extremely erosive, corrosive and high or low pressure differential applications.



1. **Optimum in Streamline Flow Characteristics.**
2. **Valve Body Construction—Standard Forged Tee, Cast Tee, or Barstock Design.**
3. **Venturi-type Throat Permits High Capacity Due to Reduced Friction Factor.**
4. **Hammel-Dahl Standard Duri-steel Heavy Gauge Superstructure.**
5. **Body and Trims of Standard Materials or Special Alloys as Specified or Recommended.**
6. **Each Application Individually Designed and Engineered.**



THREE-WAY DIAPHRAGM CONTROL VALVES

and these FEATURES

The Type 3000Q line of control valves is offered for split or by-pass process applications. Flexibility of operation is obtained where double fluid proportional operation is required. Characterized or quick-opening plugs available for proportional flow.

1. **Top and Bottom Guided Precision Ground Beveled Seat Plugs.**
2. **Through-bolted Connections on All Body Members in Flanged Construction.**
3. **Lower Seat Ring Located in Piloted Third Member.**
4. **Main Body—A.S.A. Standard Flanged Globe Valve Dimensions (Face to Face).**
5. **Standard Duri-steel Superstructure.**
6. **Sizes ½" to 2" Screwed, All Other Sizes Flanged.**
7. **Bodies in Cast Iron, Bronze and Cast Steel—Trim of Bronze and Stainless Steel.**

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For Low Power Voltage Control . . . these NEW

AUTOMATIC REGULATORS by SECO

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NO WAVE-FORM DISTORTION —
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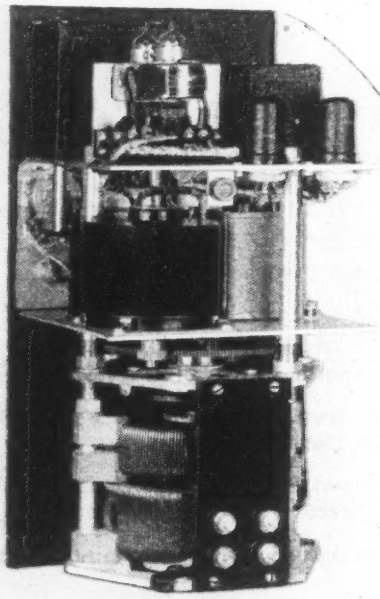
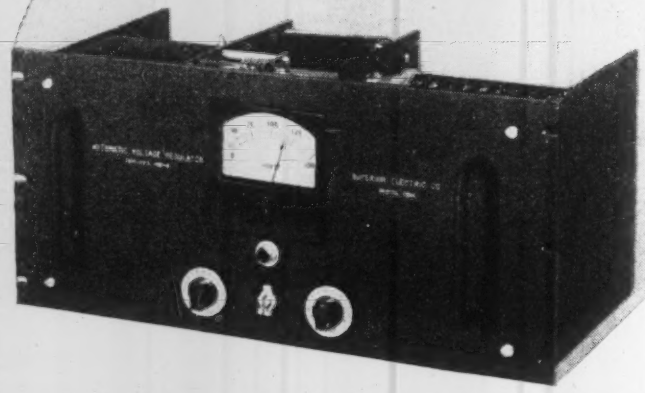
COMPACT — LIGHT WEIGHT





In the past, SECO Automatic Voltage Regulators have found wide use in maintaining constant voltage to equipment of 6 KVA capacity and greater. The introduction of SVR 4101 and SVR 4102 provides the SECO type of electronic voltage control for 1 and 2 KVA applications.

These new models possess many notable improvements to supplement the remarkable characteristics of larger SECO regulators. In addition to such features as zero wave-form distortion, high efficiency and adjustable output voltage, the SVR 4101 and SVR 4102 are compact and light weight. As illustrated, these models are available in self-contained cabinets and in rack units for installation as a component part of existing equipment.

SPECIFICATIONS

*Type	Input Voltage Range	Nominal Output Voltage	Output Voltage Range	Phase	Output Current	Output KVA	Over-all Dimensions
SVR 4101	95-135	115	100-120	1	10	1	$9\frac{1}{2}$" x 10" x $19\frac{5}{8}$"
SVR 4102	95-135	115	100-120	1	20	2	$9\frac{1}{2}$" x 10" x $21\frac{1}{2}$"
SVR 4106	95-135	115	100-120	1	52	6	$9\frac{1}{2}$" x 10" x $26\frac{1}{2}$"

*When the regulator is used for mounting in customer's rack, add the letter "R" to the type number. For table or wall mounting add the letter "H".

Detailed information is gladly given by SECO engineers upon request.

Send for Bulletins 149 SI and 163 SI

SUPERIOR ELECTRIC COMPANY

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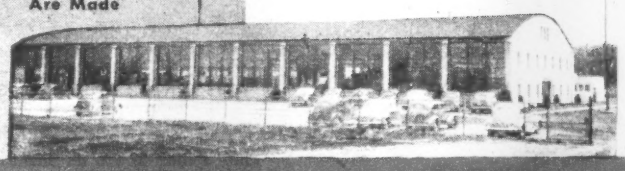
THE MOBILE UNIT INCLUDES:

(1) a set of 83 inspection grade gage blocks, (2) a four-range electric comparator, (3) optical flats, (4) Monolite, (5) master flat, (6) master square, (7) parallels, (8) pointed accessories, (9) gage block holders to make gage combinations, (10) precision surface plate, (11) a complete set of instructions on the use of every instrument, (12) set of 3 straight edges, each with 4 blades, (13) 5-inch sine bar, (14) magnifying light, and (15) a vernier gage block.

Where DoALL Gages Are Made



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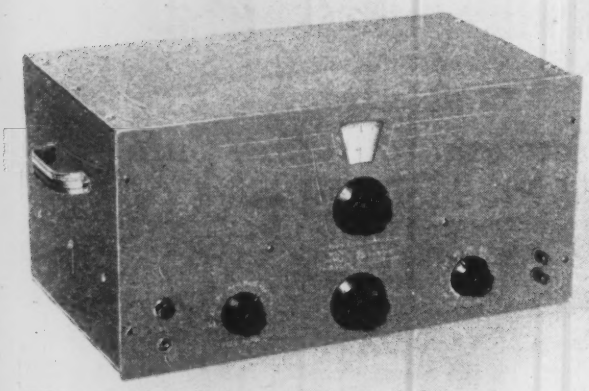
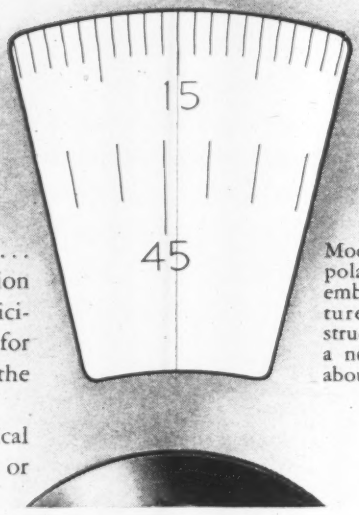
A LIFETIME of SPLIT-HAIR ACCURACY
is Standard Equipment
with Every -hp- Instrument



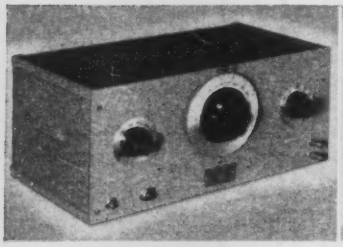
MODEL
200-I



Model 200-I is a new interpolation oscillator which embodies many new features. New, rugged construction, new circuit and a new accurate dial. Ask about it.

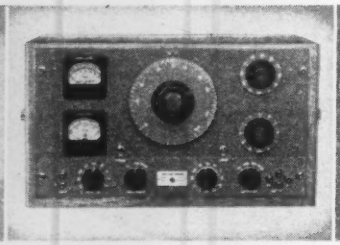
"Guess-testing" belongs to the era of crystal sets and silent pictures... Radio and electronics of today *and tomorrow* demand the use of precision testing and measuring instruments. Hewlett-Packard engineers anticipated this demand. There is a standard -*hp*- instrument available for making every important test and measurement *with insured accuracy* in the audio frequency field.

A few of these instruments are illustrated below... complete technical information will be sent on request. For special applications, a note or sketch outlining your problem will receive prompt attention.



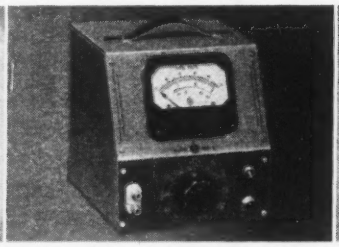
RESISTANCE-TUNED AUDIO OSCILLATORS

Require no zero setting...several models available to cover frequency ranges from 2 cps to 200 kc.



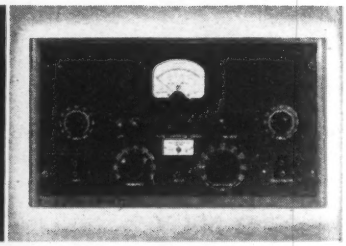
AUDIO SIGNAL GENERATORS

Three models—205-A, 205-AG, 205-AH—provide frequency ranges from 20 cps to 100 kc.



VACUUM TUBE VOLTMETERS

Make accurate voltage measurements from 1 cycle to 1 megacycle, cover nine ranges, (.03 volts to 300 volts) with full scale sensitivity.

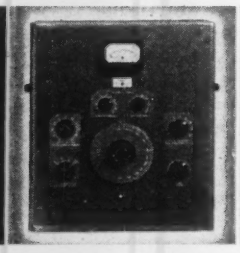


DISTORTION ANALYZERS

Three models available—320-A, 320-B and 325-B—to provide frequency coverage from 30 cps to 15 kc. Model 325-B incorporates a vacuum tube voltmeter

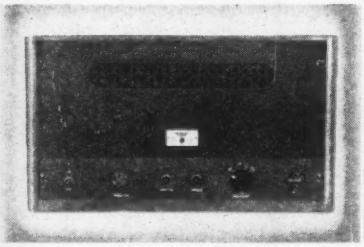
ELECTRONIC FREQUENCY METER

The Model 500-A is designed to measure the frequency of an alternating voltage from 10 cps to 50 kc. Overall accuracy is ± 2% of full scale value.



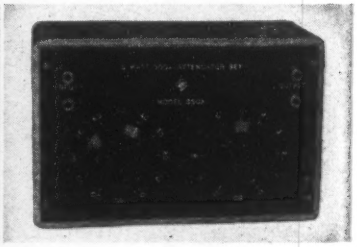
HARMONIC WAVE ANALYZER

Measures individual components of a complex wave over a frequency range of 30 to 16,000 cps. The selectivity can be varied continuously, making the analyzer adaptable to a wide variety of measurements.



FREQUENCY STANDARDS

The Model 100-B supplies standard frequencies of 100, 1,000, 10,000 and 100,000 cps, all of which are available simultaneously.



ATTENUATOR AND VOLTAGE DIVIDERS

The Model 350-A consists of a 10 db and a 100 db bridged-T attenuator, providing a total of 110 db attenuation variable in 1 db steps. Other attenuator and voltage dividers can be quickly supplied.

HEWLETT-PACKARD COMPANY

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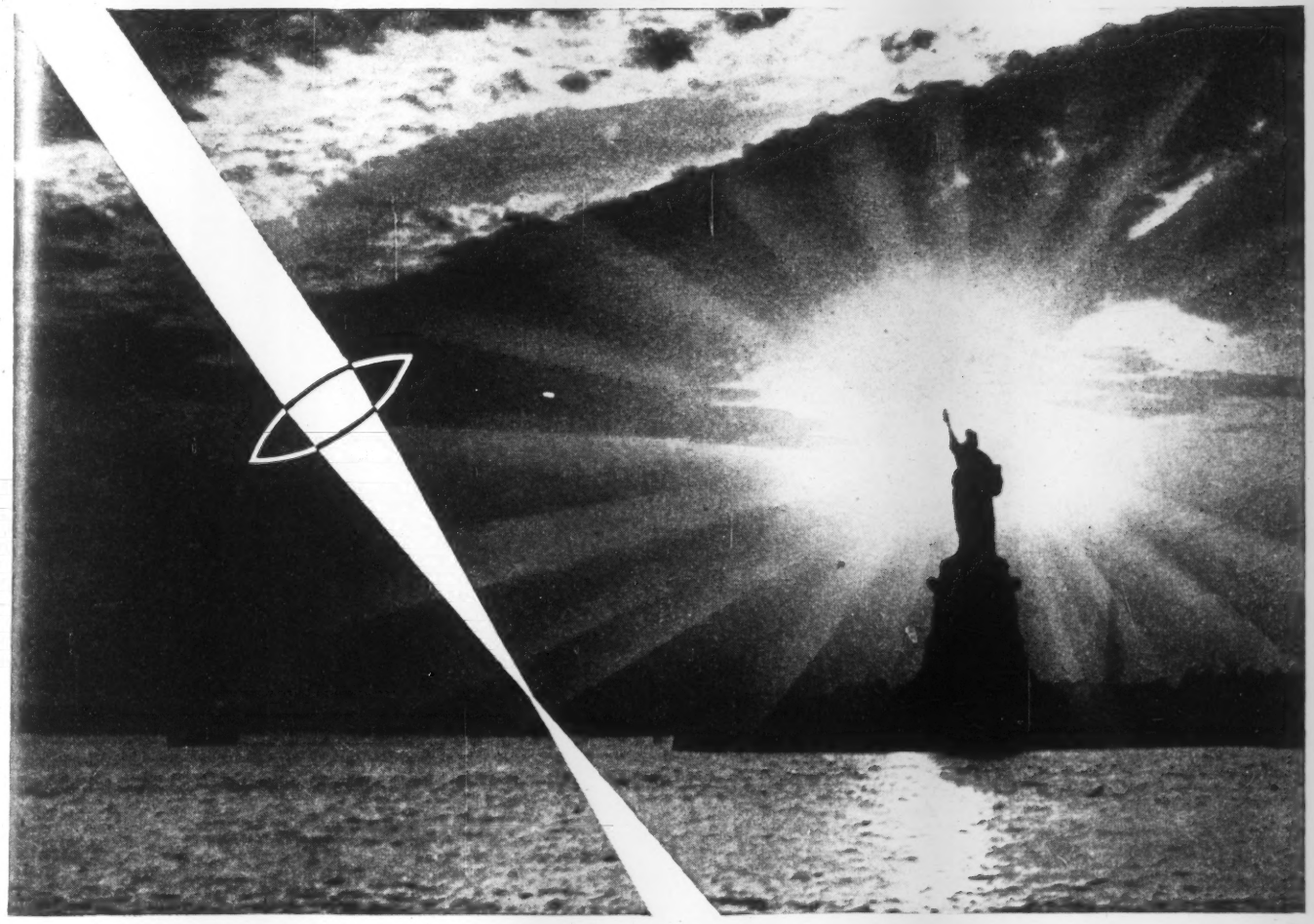

Freedom to plan for peace

Precision optics for war keep us busy — very busy.

Difficult assignments from the Army, Navy and war contract manufacturers keep coming in. But we still find time to think and plan for the days when our improved skills and techniques will be applied toward the betterment of peace-time products.

With our record for meeting the exacting demands of war goes also the obligation to do our share in helping industry reconvert speedily for a prosperous peace. We will be ready when restrictions are removed.

Manufacturers who bring their post-war optical problems to us, find a cooperative attitude and a rich background of experience that are a great aid to sound product planning. Our compact group of precision lens technicians have been trained in a plant that specializes in supplying optical components to those who make complete products. Nothing else is made here.

We have done much development work in electronic optics and in other optical fields. Possibly you have a problem for which we already have a solution.

for precision OPTICS *come to*

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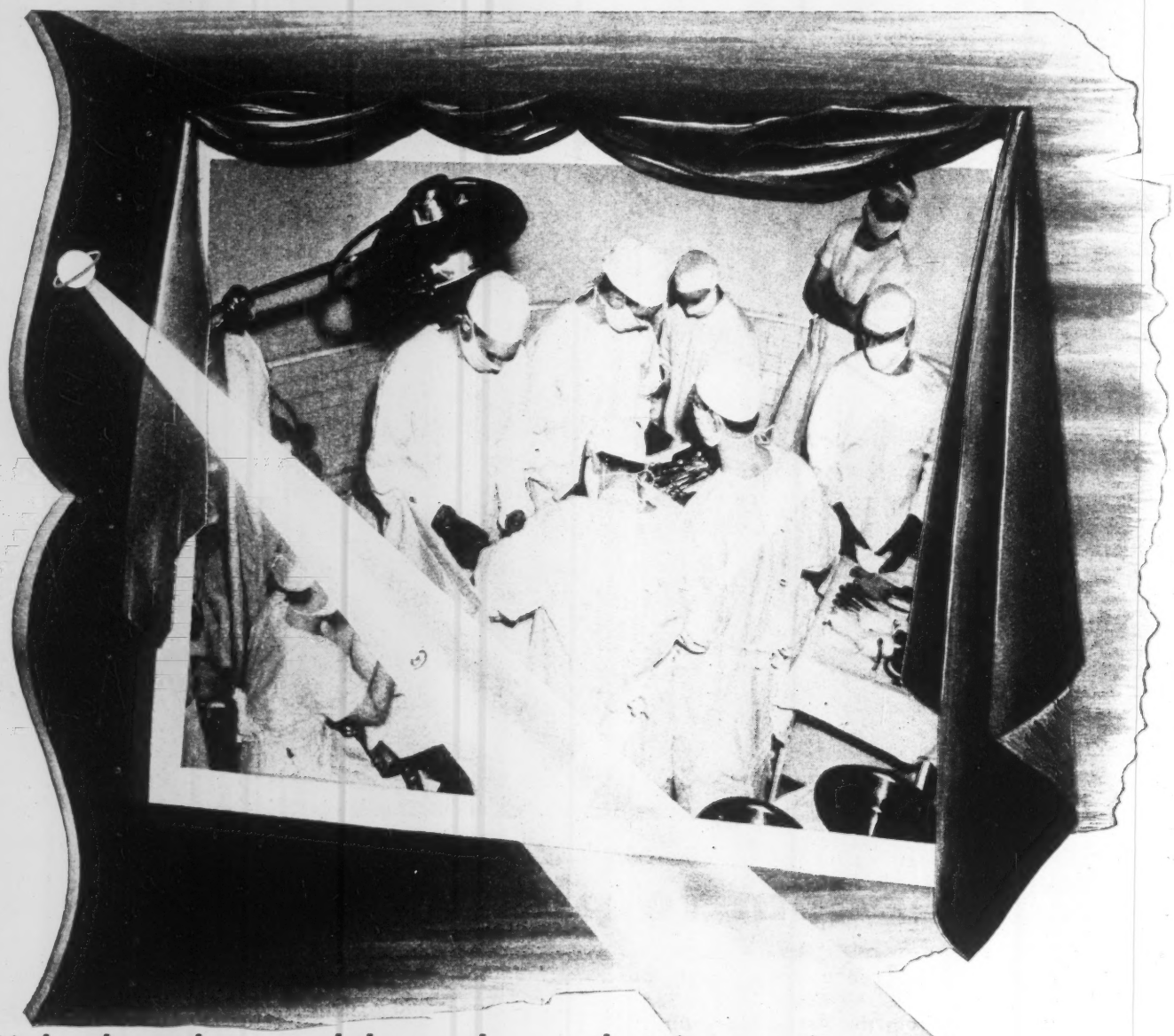

Light through an earlobe works an electric meter!

Any light source can be made to operate meters and meter relays without costly, bulky amplifiers. Luxtron* photocells, developed and manufactured by Bradley Laboratories, do this today for many purposes... such as looking at a patient's earlobe and instantaneously telling you the oxygen content of his blood . . . at a warehouse and warning of fire . . . or at a furnace to gauge its temperature.

New chapters in the story of the simplest way to transform light into electric energy are daily written by Bradley's Luxtron photocells. For information on how they can help you, write Bradley Laboratories.

*TRADE MARK REG. U. S. PAT. OFF.

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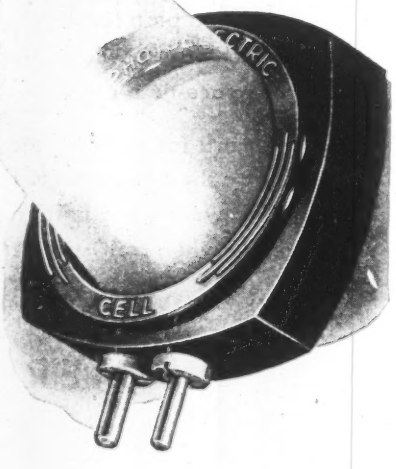
Bradley applies knowledge of electrical circuits to the development and manufacture of a unique line of "Coprox" rectifiers. Write for illustrated bulletin giving ratings and special advantages.



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what goes on in, here is a military secret

WHAT COMES OUT is a revelation in

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Housed in this block-long Sherron Electronics building is a busy laboratory in which many valuable discoveries have come to light. Here has been developed the widely used Sherron Test Units that are serving many of America's foremost electronics manufacturers in maintaining the quality control so vital to the integrity of their products. Here, working full time, day and night, a corps of electronics engineers are blazing new trails. Here a hard-working staff of technicians and scientists are evolving new applications of the amazingly versatile tool that is electronics.

Sherron Electronics

We invite correspondence with manufacturers who are thinking in terms of post-war electronics. They will find our specialized experience, resources and skills of real value.

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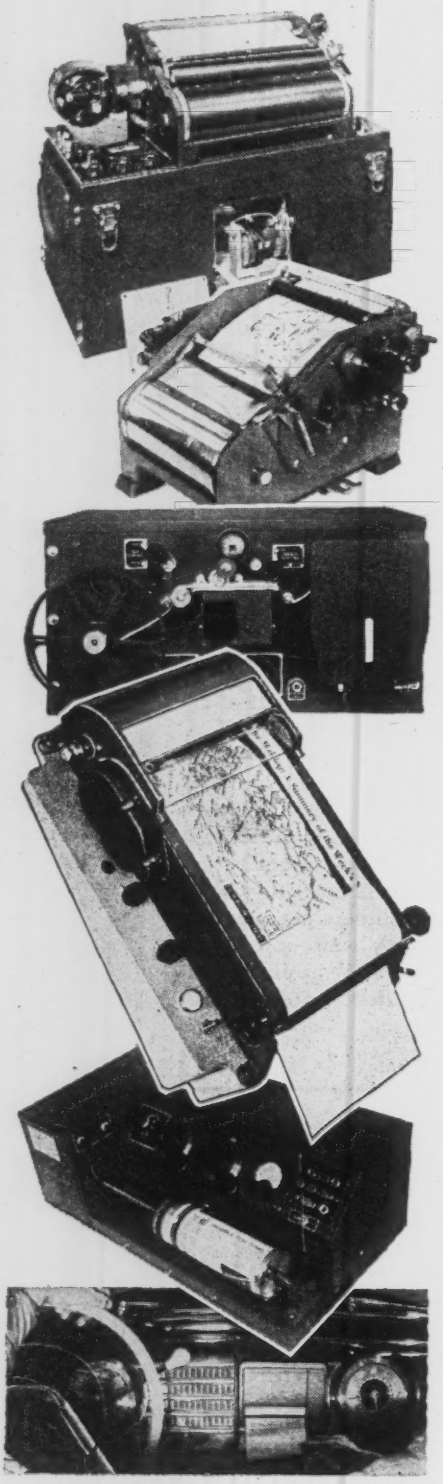

OUR YEARS OF EXPERIENCE, and cumulative skills, in the Designing and production of RADIO COMPONENTS, are now being used in making equipment which covers **the entire field of FACSIMILE.**

Actual service, as found in war and communication work under all conditions, has given a PRACTICAL quality to our equipment which, under ordinary conditions, would not have been obtained in years of engineering with limited application.

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1. **Some of our equipment has been used for the transmitting and receiving of photographic pictures of reasonably high resolution (such as the war pictures now appearing in the news).**

2. **Continuous Recorders—of the type whose value has been proven on National and International news service circuits—are now on their way to the Orient, to be used for the receiving of the so-called "picture" languages.**

3. **Also, through the use of ALFAX (the first high-speed black and white permanent recording paper), HIGH-SPEED Signal Analysis Equipment has been made possible for various laboratories and Government Departments. Other equipments have employed Teledeltos Paper for message work and other purposes.**

4. **The ability of ALFAX Paper and ALDEN Machines to record impulses *as they occur*, without the inertia problems of many previous methods, has made possible other recorders at various speeds (including slow). They will record a whole day's history of related phenomena, with time indicated, and often—with self-calibrated linear reference marks for ready interpretation.**

5. **ALDEN tape Recorders (recording medium, Ink)—have been designed to operate with a minimum of trouble and adjustments, and have PROVED MOST SATISFACTORY in day-to-day service.**

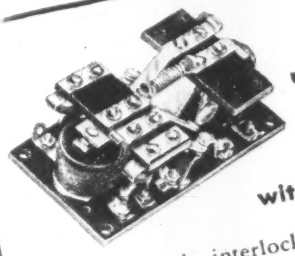
ALDEN PRODUCTS COMPANY

117 North Main Street

BROCKTON (64C), MASSACHUSETTS

• • • • • • • •

FIVE OF THE 5,312 RELAY TYPES



A NEW "MEMORY" RELAY

with simplified interlock

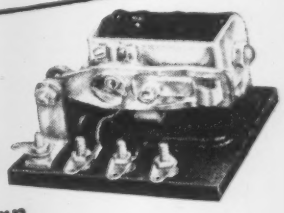
A new style interlock represents latch-in relay construction in its simplest, most dependable form. Design of this Struthers-Dunn 50XBX series simplifies make-before-break, or break-before-make contact combinations. Contacts do not interrupt coil circuit until the "throw" is completed and they are latched in new position. Built to aviation specifications.

VACUUM SWITCH KEYING RELAY

The extreme reliability with which this Struthers-Dunn Type 78CCA100 Vacuum Tube Keying Relay holds its adjustments is the direct result of a rigid and simplified design utilizing an absolute minimum of parts. Exceptionally sturdy—designed for aircraft. All parts readily accessible.

7 poles including one D.T. pole handling high-voltage r-f currents by means of a vacuum switch. High-voltage parts rounded to reduce corona.

SENSITIVE SNAP-ACTION



in a new, simplified design

Applications for the Struthers-Dunn Type 79XAX Sensitive Snap-Action Relay range from vacuum tube circuits, to overcurrent protection, pulsing circuits, and jobs where extremely close differential or extreme sensitivity are required. Contacts remain in position *with full pressure* up to the instant of transfer. Write for Bulletin No. 251.

SHOCKPROOF to 90 G's

Here's a relay that won't operate unintentionally as a result of shock or vibration—the Struthers-Dunn Type 17AXX designed to meet exacting B2A specifications. Small in size, light in weight, it meets and exceeds all specifications for such services.

WRITE—*for your copy of the big Struthers-Dunn Relay Catalog and Data Book . . .*

EXTRA HEAVY-DUTY CONTACTS

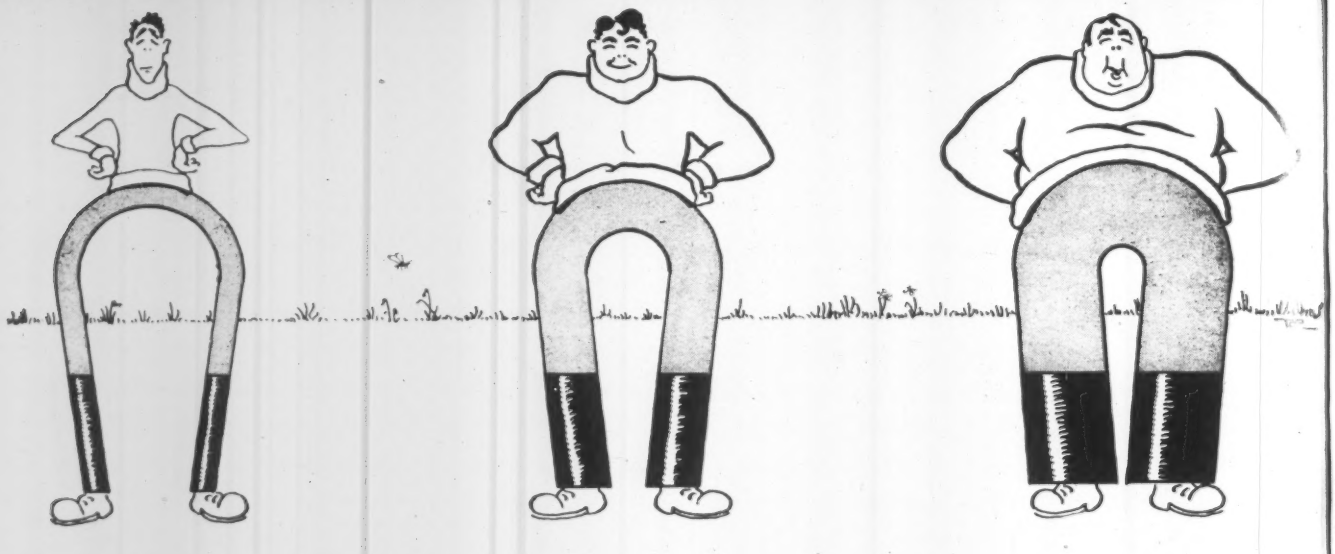
Struthers-Dunn Nutcracker Type 61HXX100 meets the call for relays for extreme services, particularly where severe overloads may cause trouble on units having a less generous heavy-duty contact safety factor. Typical applications include those such as aircraft landing light controls, or controlling a number of solenoids simultaneously. Readily adaptable to different specifications.

STRUTHERS-DUNN, INC., 1321 ARCH ST., PHILA. 7, PA.

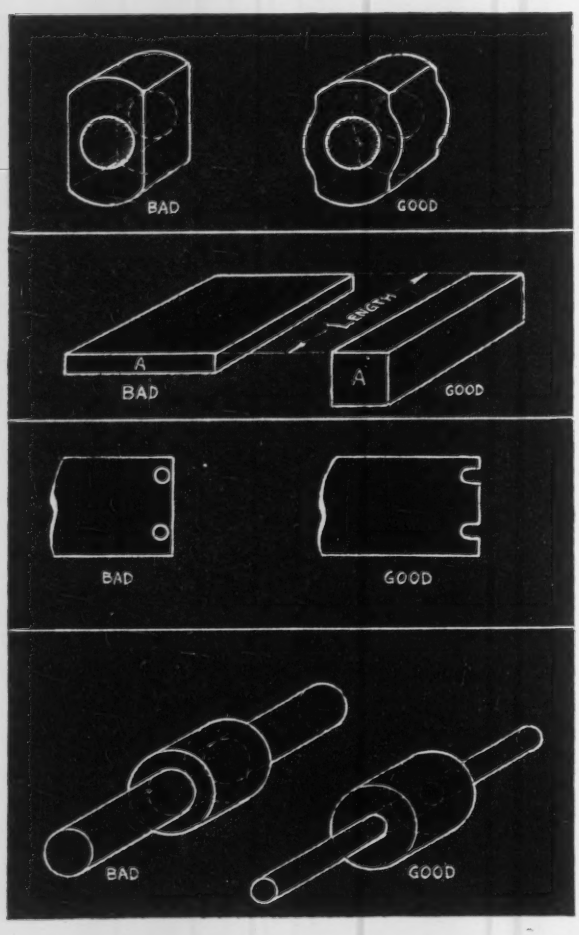
STRUTHERS-DUNN

5,312 RELAY TYPES

DISTRICT ENGINEERING OFFICES: **ATLANTA • BALTIMORE • BOSTON • BUFFALO • CHICAGO • CINCINNATI • CLEVELAND DALLAS • DENVER • DETROIT • HARTFORD • INDIANAPOLIS • LOS ANGELES • MINNEAPOLIS • MONTREAL NEW YORK • PITTSBURGH • ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO • WASHINGTON**



NEITHER TOO FAT NOR TOO THIN!



That skinny chap at the left could do with some setting up exercises. An extended course at some accredited physical culture school would put some flesh on his bones, where it belongs. And as for that rather portly gentleman on the right, he's no Superman. He's too fat.

Magnets, like people, should be well proportioned. Just the right amounts of metal at the right places give them the mechanical strength to withstand the necessary grinding down and subsequent annealing operations. The shape as well as size has a bearing on the energy content desired. A few simple rules on proper proportioning which will help in designing magnets are discussed in our pamphlet "PERMANENT MAGNET DESIGN." We'll be glad to send you a copy.

CINAUDAGRAPH CORPORATION

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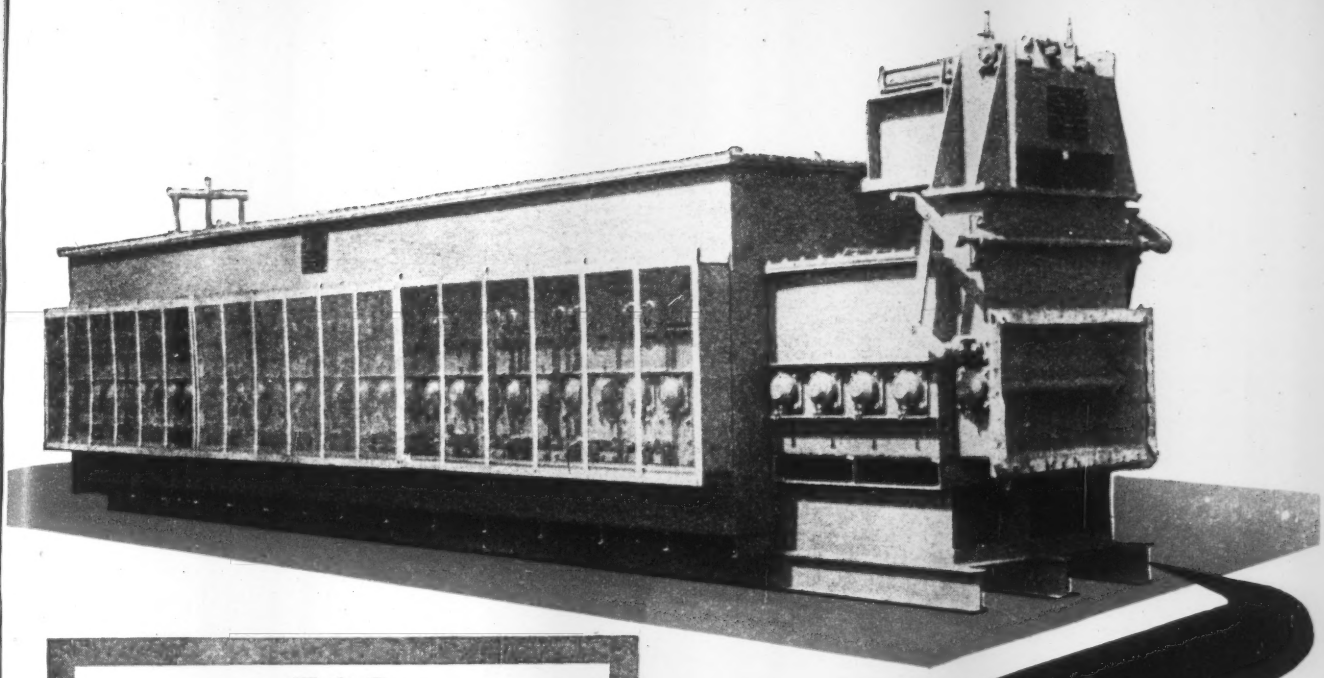
3-CC 4



FOR POWDERED METALS

EXPERIENCE POINTS TO

DREVER SINTERING FURNACES

This Drever continuous electric roller hearth furnace, complete with Ammonia Dissociator, has recently been installed in the plant of a leading producer of powdered metals.

The dissociated ammonia atmosphere used is maintained at 4" water pressure—with minimum leakage of atmosphere gas.

Net working area of the furnace proper, less the cooling chamber not shown, is 2' 9" wide x 22' long. Special seals, air operated doors, and complete automatic control are included for maximum operating efficiency.

The experience of the Drever Company in designing furnace equipment for powdered metals is available to all engaged in, or contemplating such production.

THE DREVER CO.

782 E. VENANGO ST., PHILA. 34, PENNA.

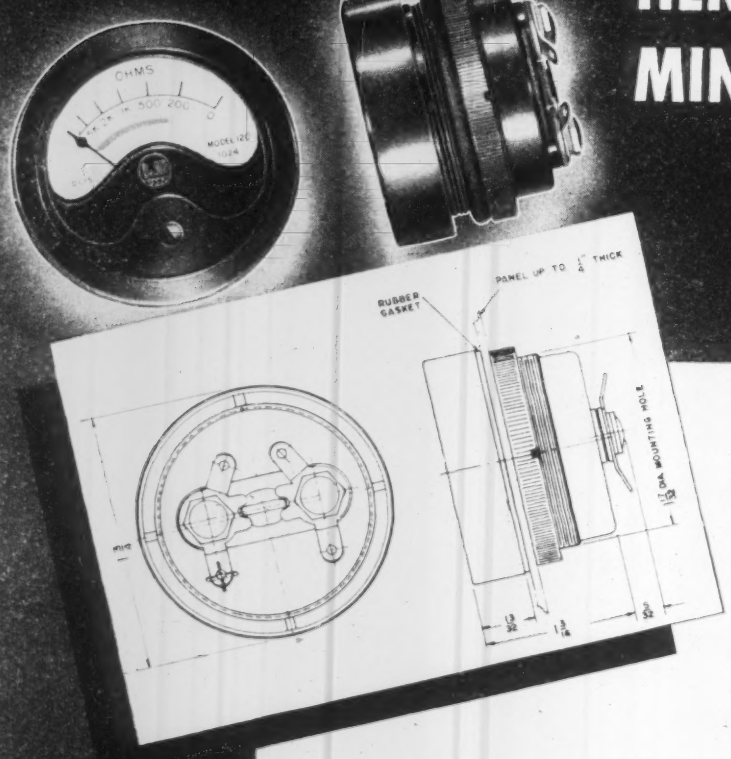
PRESSURE QUENCHES · CONTINUOUS FURNACE LINES · HEAT TREATING FURNACES

NEW YORK AND NEW ENGLAND—GERALD B. DUFF, 68 CLINTON AVE., NEWARK 5, N. J.

DeJUR Presents to the Electrical Industry

HERMETICALLY SEALED MINIATURE 1½" METER

(MODEL 120)



Completely Immersion-proof Throughout

1 Hole Mounting for Easy Installation

Movement Built to A.S.A. Specifications

Ideal Component for All Small Equipment

- The smallest meter available, yet capable of performing a full-scale task in a variety of applications.
- Hermetically sealed, it can be immersed in water for as many as seven days without harm to its mechanism.
- The case, as well as the glass, is completely waterproof—thus, if the glass breaks, water still cannot penetrate.
- Since the equipment in which this meter is used must also sustain immersion, termtnal studs are waterproof sealed.
- Supplied with the Model 120 is a waterproof gasket for mounting the instrument flange to the panel.
- Quickly and easily installed—only one hole—no drilling, no screws necessary—just tighten on with a ring.
- Ideal for all small equipment—present or postwar. Write for complete specifications and prices.

ARMY E NAVY

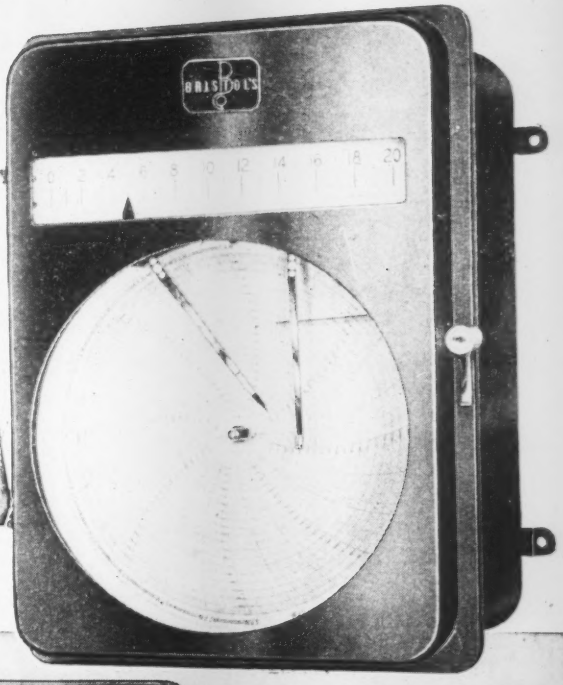
SUPPORT THE RED CROSS WAR FUND

DeJUR-AMSCO CORPORATION

GENERAL OFFICE: NORTHERN BLVD. AT 45th STREET, LONG ISLAND CITY 1, N. Y.

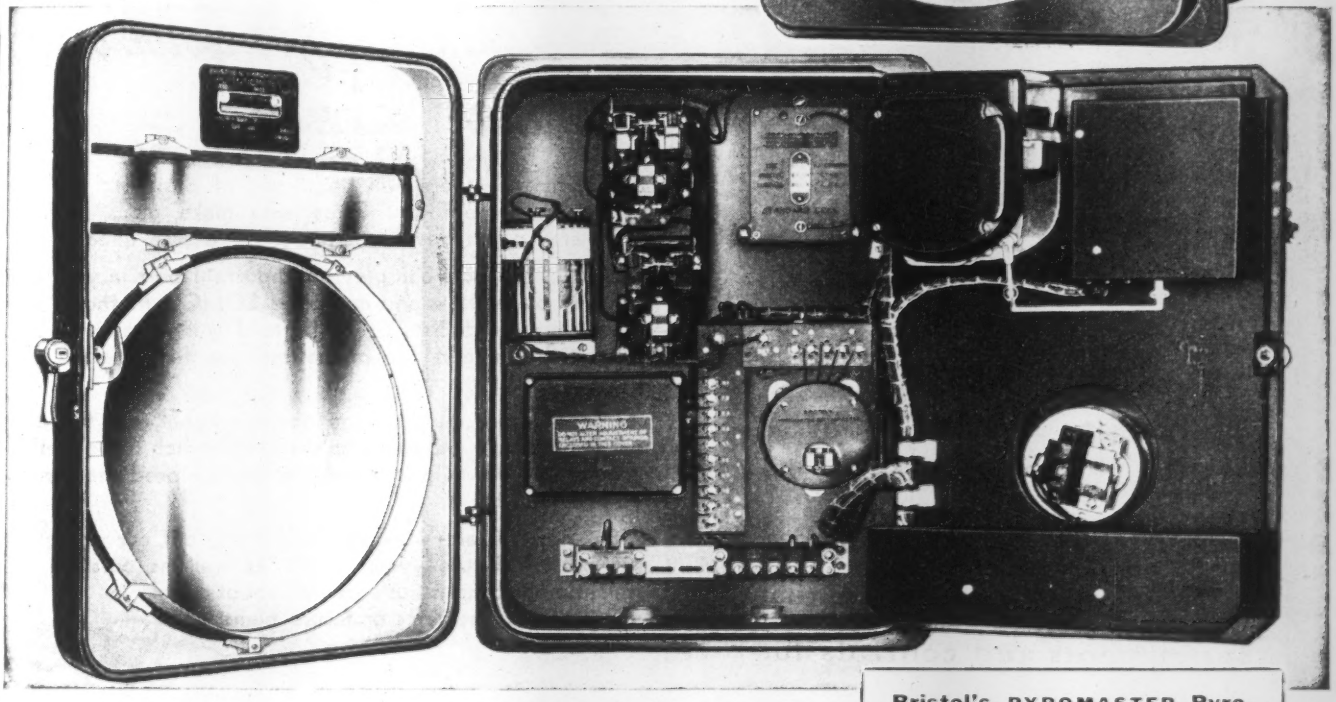
Bristol's PYROMASTER

A Self-balancing Potentiometer for Recording, Indicating and Controlling Industrial Processes



REDESIGNED EMBODYING NEW FEATURES

1. Hinged panel for accessibility.
2. Standard Cell for accuracy.
3. High-torque motor for ruggedness.
4. Totally enclosed relays and galvanometer.
5. Enclosed tarnish-resistant slide-wire.
6. Large easily read straight-line scale.



Pyromaster Pyrometer Electric-Type Controller, door open and panel swung out

ALL PARTS ACCESSIBLE: All parts of the Pyromaster are accessible even when the instrument is in full operation. The dial and recording mechanisms are mounted on the front of a hinged reinforced steel panel, which can be swung out of the case as shown above. The slide wire and potentiometer mechanism and, in the case of controllers, the control mechanism are mounted on the back of the panel. Each part or unit can be serviced in place or removed without disturbing any other part.

Bristol's PYROMASTER Pyrometers are available in the following types of instruments for temperatures up to 3600° F.

Electric-Type Controllers
Air-Operated Controllers
Single-Pen and Two-Pen Recorders
Dial Indicators
Time-Temperature Controllers
Radiation Pyrometers

Complete facts in Bulletin P1200. Address 113 Bristol Road

BRISTOL

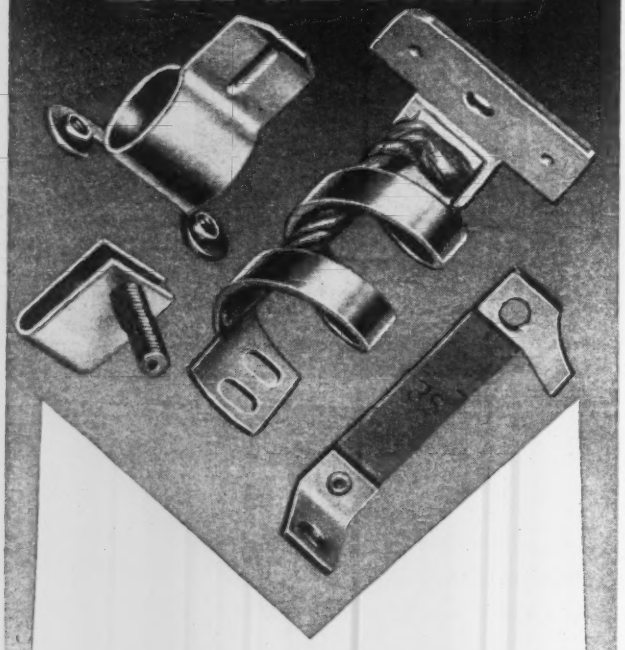
Engineers Process Control for Better Products and Profits

THE BRISTOL COMPANY, Waterbury 91, Connecticut

The Bristol Co. of Canada, Ltd.
Toronto, Ontario

Bristol's Instrument Co., Ltd.
London, N. W. 10, England

CHACE *Thermostatic* BIMETAL



35 types of Chace Thermostatic Bimetals in sheets, strips, shapes to specifications, and sub-assemblies are being supplied to manufacturers for use in vital instruments and controls for planes, ships, tanks and trucks.

Chace is always ready and anxious to cooperate with you on any problems pertaining to actuating elements for temperature responsive devices.

W.M. CHACE CO.

Manufacturers of

Thermostatic Bimetals and Special Alloys

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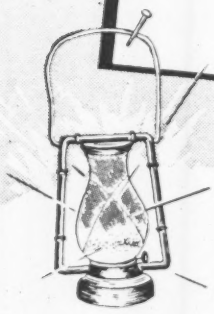
WARNING

Competition Ahead



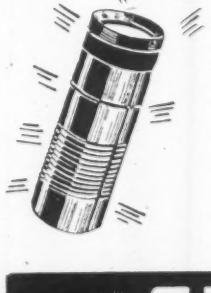
Keep posted on **SOMCO** *developments for your own postwar plans . . .*

After the war there will be plenty of business . . . and plenty of competition. Those who make plans now for postwar product development will be a step ahead.

SOMCO products can play an important part in your own postwar plans. New and improved SOMCO methods, new ideas, new products . . . all born of war experience . . . will be broadened for peacetime use far beyond their present military applications.

As soon as we get the "go ahead" signal, our facilities, our engineering and research staffs will switch to peacetime production—to help you produce better products for the optical industry.

Right now we are working for Victory, but our sights are set on the future—your future as well as ours. In the meantime, consult us freely about your present problems or future plans.



SOMCO PROJECTION LENSES

Complete line of commercial, high speed color corrected projection lenses for 8mm, 16mm and 35mm film and slide projectors. Drawing shows 35mm double frame projection lenses, various focal lengths.

SIMPSON

OPTICAL MANUFACTURING CO.

3200 WEST CARROLL AVENUE • CHICAGO 24, ILL.

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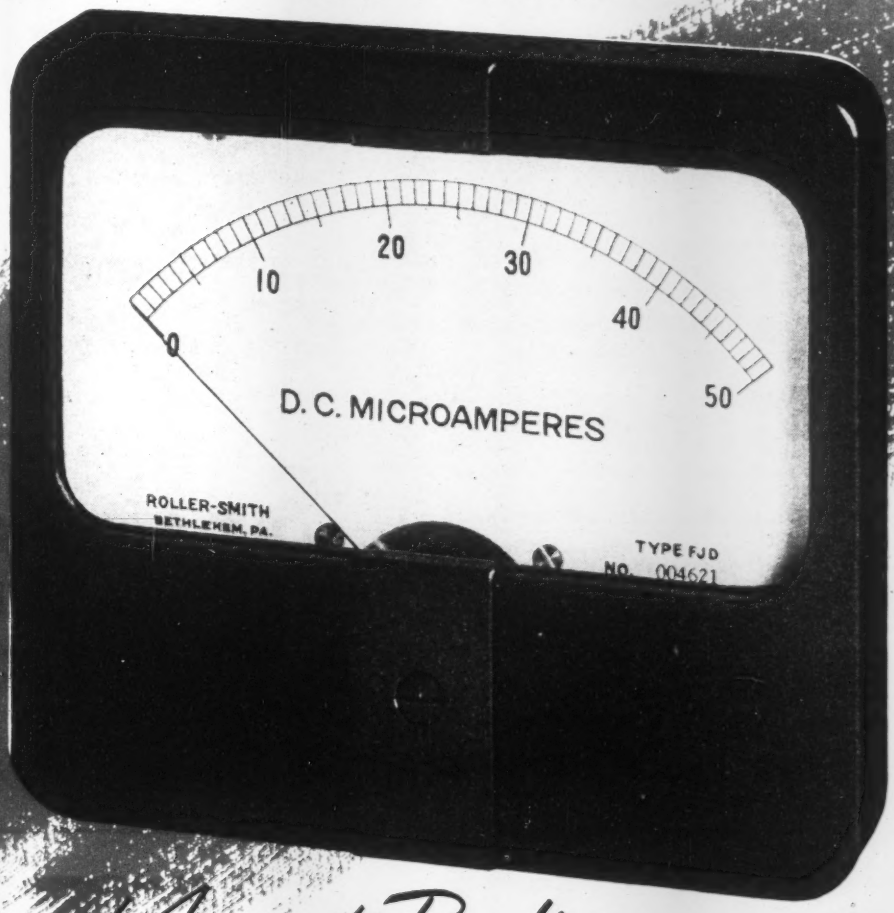
PROJECTION LENSES • CAMERA LENSES • PRISMS
OPTICAL FLATS • SOUND OPTICAL SYSTEMS AND
LENS COATING FOR LOW REFLECTION

ROLLER-SMITH 4.5" PANEL INSTRUMENTS...

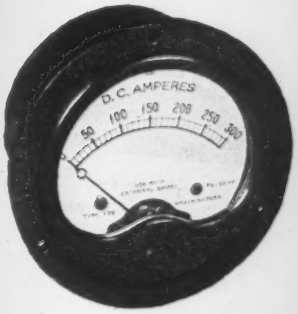


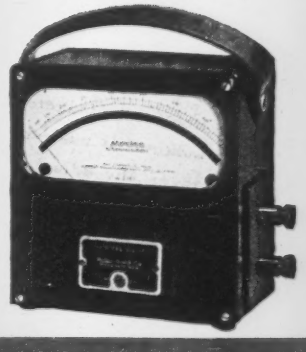
for Quick and Accurate Readings

Where panel conditions permit their installation these 4.5" semi-flush Bakelite case instruments provide maximum readability. Scale length of d-c instruments is 3⅞ inches and for a-c instruments is 3 21/32 inches. All instruments except rectifier types are accurate within 1% of full scale value at any point on the scale. Rectifier types, approximately 5%.

Incorporating the long life and dependability developed during 40 years of fine instrument manufacture, R-S 4.5" panel instruments have a diversified field of application which includes: Radio Transmitters; Control Panels; Battery Testers and Chargers; Electronic Tube Testers and Analyzers; Automotive Analyzers: Instrument Test Units; Sound Movie Equipment; Motion Picture Control Panels: Arc Welding Equipment; Experimental and Amateur Radio; General Electrical Laboratory Testing; General Communications, etc.

Any practical range can be supplied on short notice in d-c and a-c (Repulsion iron-vane and Rectifier type) models, with single or multi-range scales. Correspondence is invited.





OTHER R-S INSTRUMENTS: *Panel, switchboard and portable instruments of practically every standard size, shape, capacity, type and style are included in the R-S line of electrical instruments. Shown here are (upper) 3.5" Miniature Panel Ammeter conforming to American War Standard C39. 2-1944 and (lower) "Steel-Six" Portable Ammeter.*

***and don't forget . . .* BUY WAR BONDS**

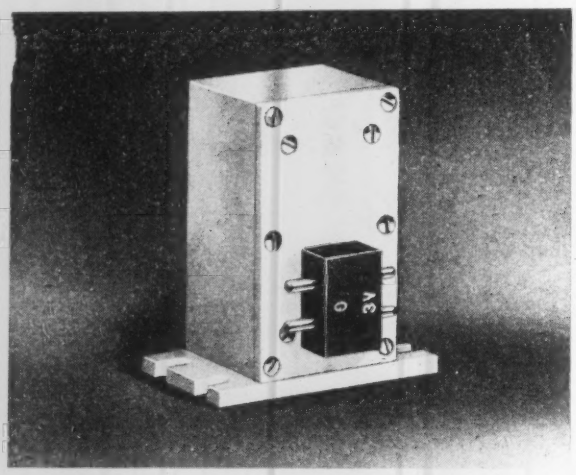
ROLLER SMITH

Sales Representatives in all Principal Cities

ROLLER-SMITH BETHLEHEM, PENNA.

Canadian Plant: ROLLER-SMITH MARSLAND, LTD., Kitchener, Ontario

STANDARD AND PRECISION ELECTRICAL INSTRUMENTS • AIRCRAFT INSTRUMENTS • SWITCHGEAR • AIR AND OIL CIRCUIT BREAKERS • ROTARY SWITCHES • RELAYS • PRECISION BALANCES



SPECIFICATIONS OF MODEL A F SHOWN:

Range: 12-0-12 G

Natural frequency: 400 c.p.s.

Power requirement: 3 volts at 50 milliamperes D. C.

Output: 150-0-150 microamperes, closed circuit. (ample for recording oscillograph galvanometers such as Heiland Types A or B)

Weight: 2 ounces.

Temperature compensated over a wide temperature range.

Other models available in various ranges.

ACCELEROMETERS

We offer a series of linear accelerometers which set a new standard for simplicity and accuracy in acceleration measurements. No carrier systems, amplifiers, or bridge balance circuits are required.

Sold under license from Curtiss-Wright Corporation.

STATHAM LABORATORIES

8222 Beverly Boulevard
Los Angeles 36, California

DESIGNERS AND MANUFACTURERS OF SCIENTIFIC INSTRUMENTS

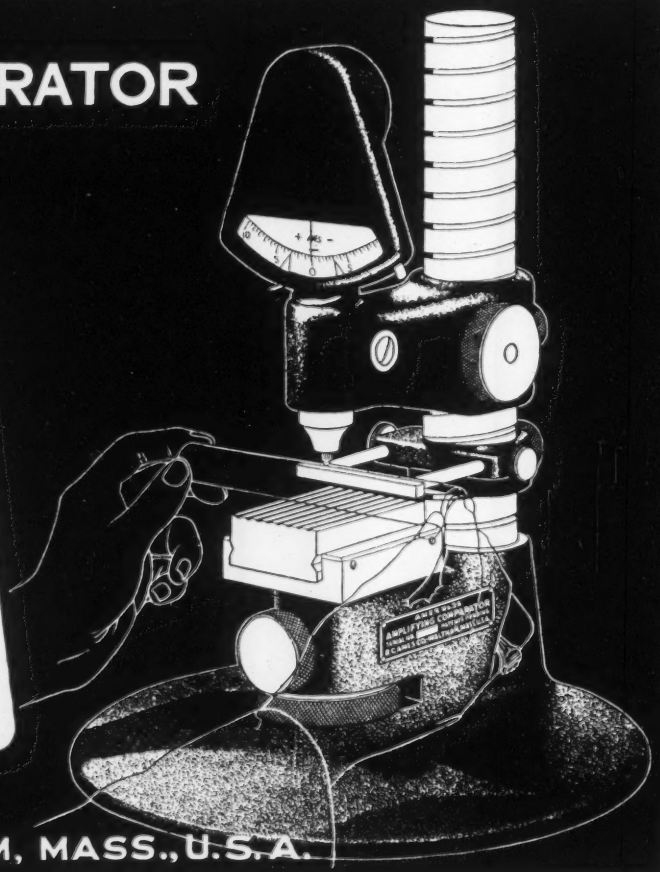
AMES No. 26 COMPARATOR

This precision built Comparator stands solidly on a large diameter base and is heavily constructed to eliminate all spring. It is intended for use in making comparisons of duplicate parts for size and will indicate the most minute variations on the dial, with ability to give repeat readings.

The cast iron base supports the steel upright column, which is grooved to provide an adjustable stop for the indicator bracket. Fine adjustment of indicator is made by moving dial with outside lever. The adjustable stop assembly helps to locate work on the hardened and ground anvil.

SPECIFICATIONS

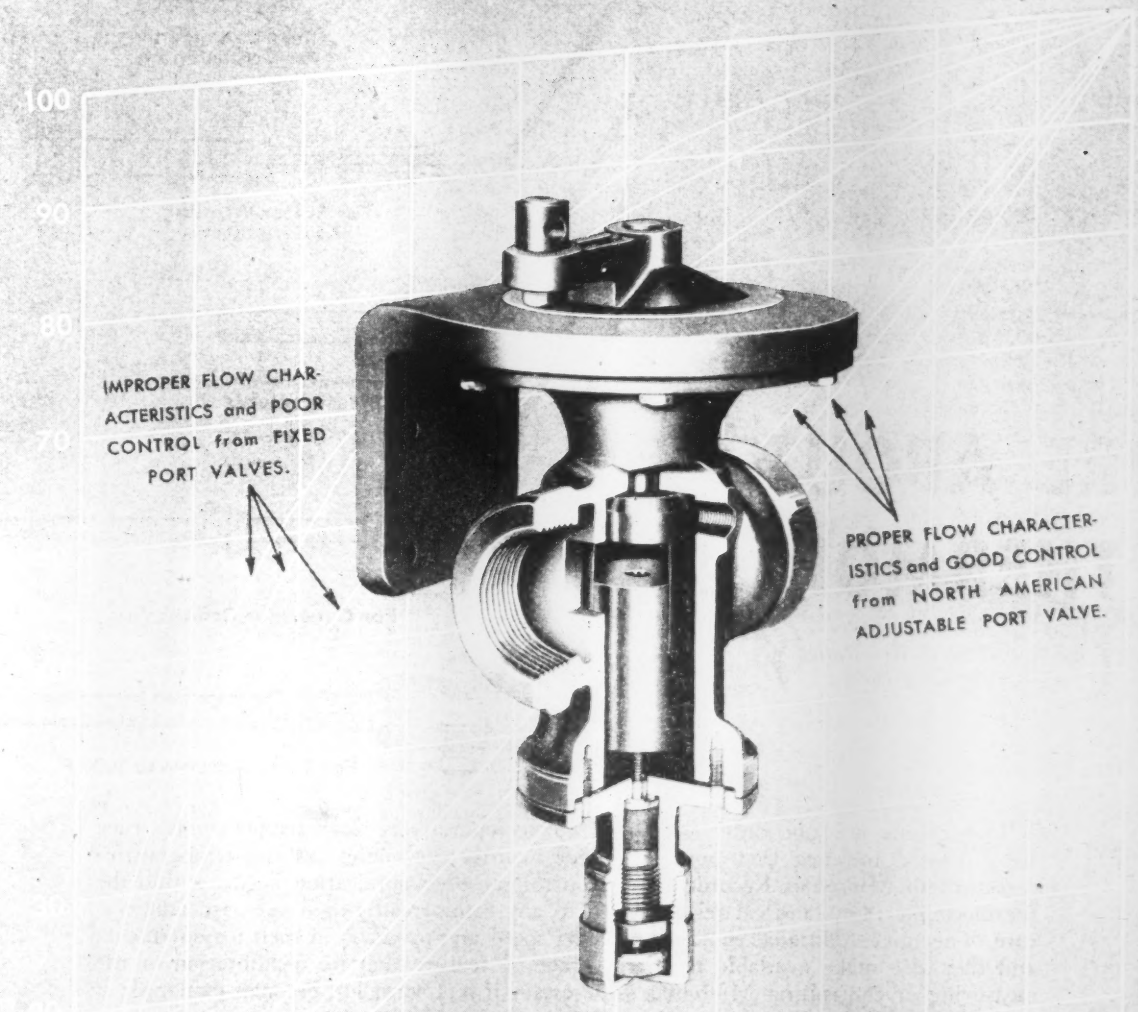
Total height 15". Base diameter 11"
Total measuring capacity 6"
Fan Head total range .002"
Distance from contact to front of Post 3½"
Anvils 2⅛" x 3¼". Special anvils to order
Approximate weight 40 pounds



B. C. AMES CO., WALTHAM, MASS., U.S.A.

NORTH AMERICAN

Adjustable Port Valves for Flow Control


100
90
80
70
IMPROPER FLOW CHARACTERISTICS and POOR CONTROL from FIXED PORT VALVES.
PROPER FLOW CHARACTERISTICS and GOOD CONTROL from NORTH AMERICAN ADJUSTABLE PORT VALVE.

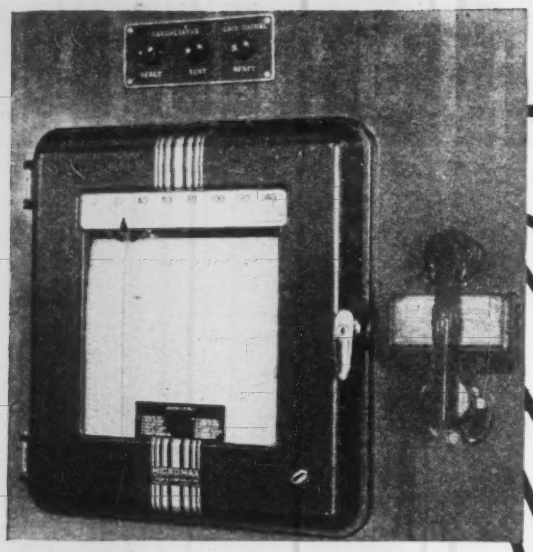
for Air, Gas, Oil, Steam and Water

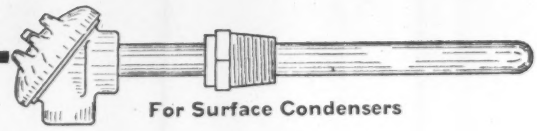
THE NORTH AMERICAN MANUFACTURING COMPANY

MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL

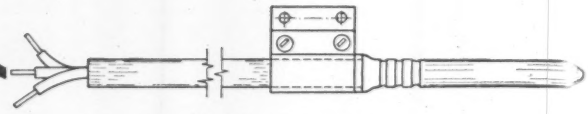
BRANCH OFFICES *with* FIELD ENGINEERS *in* PRINCIPAL CITIES

CLEVELAND, OHIO

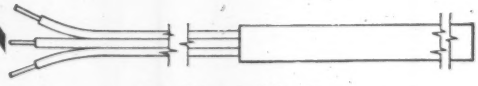




For Surface Condensers

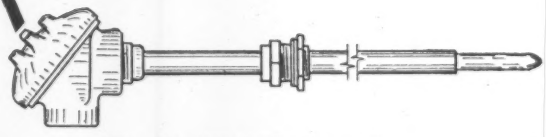


For Heating and Air Conditioning

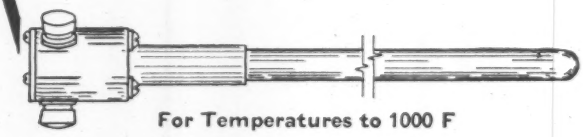


For Stator Winding In Generators

For Temperature-Difference Measurements



For Generator Cooling Air



For Temperatures to 1000 F

MORE ABOUT THERMOHMS

(*L&N Electrical Resistance Thermometer Bulbs*)

Thermohms are not only specialized for comparatively low temperatures—they were created for just that purpose. Used, like thermocouples, as the temperature-detectors for Micromax Recorders and Controllers, their application begins within the thermocouple range and carries on down to any commercially-used sub-zero temperature. They give additional choice in securing speed and precision in such measurement; and they also make available the great practical feature that no recalibration of the measuring or controlling Micromax is necessary if a Thermohm becomes damaged; it is simply removed and replaced with a new unit.

A standard cable connecting the Thermohm to its Micromax instrument makes it possible to measure near *or far-distant* Thermohms with equal accuracy, and as many as 16 Thermohms may be connected to a single Micromax to give centralized, time-saving and economical records of temperatures in buildings, large machines, etc.

Essentially, an L&N Thermohm (electric resistance thermometer) is a small coil of nickel or copper wire whose resistance changes with temperature. Thermohms are annealed and pre-aged for permanence . . . effectively sealed in one-piece brass cases. Thermohms are used with "all-weather" heads, and with protecting tubes or wells.

For more complete information on Thermohm applications and assemblies—together with Micromax instruments for recording and controlling, send for Catalog N-33C.

Jrl. Ad NS42(1)

LEEDS & NORTHRUP COMPANY, 4955 STENTON AVE., PHILA. 44, PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

depends on me!
A Slogan For Every American

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

The Second Intersociety Meeting

The second meeting* of the conference for the Formation of a National Instrument Society met at Chicago February 17. The Societies represented at the meeting were:

Chicago Society for Measurement and Control.

Kansas City Industrial Instrumentation Society.

New York Society for Measurement and Control.

Northern Indiana Society for Measurement and Control.

Philadelphia Society for Instrumentation.

American Society for Measurement and Control (Pittsburgh).

Instrument Society of Washington.

Instrument Society of Wayne County (Wyandotte, Mich.).

Earl C. Rieger, Past President of the Chicago Society for Measurement and Control, presided as Chairman.

The Conference adopted the name INSTRUMENT SOCIETY OF AMERICA for the national society, which name, it was considered, was simple, short and in scope included all fields and interests in instruments.

The Constitution Committee presented a draft of a constitution for the national society. From this draft a "Declaration of Policy" setting forth the scope, objectives and organization structure proposed for the Society was prepared. The Conference directed that a copy of this Declaration of Policy be sent to each of the known local instrument societies with an invitation to attend the next meeting of the conference and affiliate with others in forming the Instrument Society of America. The Declaration of Policy will also be published in the April 1945 issue of *Instruments*.

It was also directed that the Constitution Committee prepare a formulation of the benefits of a national instrument society for dissemination to the various instrument societies. This will also be published in the April *Instruments* under the title "Benefits of a National Instrument Society."

Pittsburgh was selected for the next meeting, and the date chosen is April 28, 1945. R. J. S. Pigott, President of the American Society for Measurement and Control (Pittsburgh), was named Chairman of the Pittsburgh meeting.

The Declaration of Policy states "Any person, firm or institution interested in the objectives of the Society shall be eligible for membership."

Inquiries regarding further details of the Society or the Pittsburgh meeting should be addressed to the chairman of the Pittsburgh Meeting, R. J. S. Pigott, Box 2038, Pittsburgh 30, Pa., or to the Recording Secretary, R. C. Darnell, Box 4730, Washington, D. C.

R. C. DARNELL,
Recording Secretary

*Note: The Report of the Recording Secretary on the First Meeting held in New York on December 2, 1944 is given on page 1, *Instruments*, January, 1945.

IT is a pleasure to turn this page over to a movement for which I have worked during the last twenty-one years and it may be fitting to quote, in the space left, the concluding paragraph of the very first editorial (June 1933) I wrote as editor of INSTRUMENTS:

"We are all colleagues in one esteemed profession: All men who invent, design, build, sell, specify, apply, install, service and maintain measuring instruments, meters and automatic-control equipment belong to one fraternity that strives to make better things for mankind and to eliminate human drudgery.—MFB"

AN INVITATION TO JOIN THE I. S. A.

Delegates to the Chicago organization meeting on February 17th instructed the writer to invite membership in the new national organization to be known as the INSTRUMENT SOCIETY OF AMERICA.

This invitation is extended to the various local groups now organized, or in the process of forming, and also to *all individuals who are not now in a local group.*

Referring to the Declaration of Policies* you will find the general aims and conditions covering the organization. These will be built into a Constitution and set of by-laws by the Constitution Committee, and submitted to the constituent societies for ratification.

The sooner we become amalgamated, the quicker can be brought to pass the many benefits of such an organization. We urge you to become a part of this group at once so that when Mr. R. J. S. Pigott, Chairman of the meeting called for April 28th at Pittsburgh, sends a notice of that meeting to the local societies, you will already be a member of the household.

Membership application may be made to Richard Darnell, Recording Secretary for the organizing activity, Box 4730, Washington, D. C.

EARL C. RIEGER
Chairman, Second Organization Meeting

*To be printed in the April issue of *Instruments*.

Some Recent Applications of Electronics to Industrial Process Instrumentation

By H. D. MIDDEL, Industrial Engineering Division, General Electric Co., Schenectady, N. Y.

ALTHOUGH electronics may be heralded as earth-shaking, there is no reason to believe that it will sweep aside non-electronic measurement and control methods. In radio, electronics was uninhibited by competition: there was no other medium. In the industrial measurement and control fields, however, electronics ran headlong into competing forms of instrumentation; i.e., mechanical, pneumatic, and hydraulic, all of very mature experience, and could win acceptance only through merit. It is a purpose of this article to help evaluate where and how electronics contributes to the field of process instrumentation.

By process instrumentation is meant the measurement and control of process variables such as pressure, temperature, etc. The term instrumentation is used in its physical sense to cover primary elements, measuring circuits, controllers and controlled elements, whether they be mechanical, pneumatic, hydraulic, electronic or composite.

The application of electronics to the field of industrial measurement and control is in many respects a "natural." Electron tubes are in most cases amplifiers—a necessity where low available measurement energy must be amplified to comparatively high power levels to initiate control. Electron tubes, by virtue of their low grid current characteristics, are essentially potentiometric devices and as such they satisfy a condition often necessary to accurate measurement. The gas type tube, while not an amplifier, can control large amounts of power and its trigger action makes it useful as an almost inertialess relay. Electron tubes and their associated circuits incorporate such a wide range of abilities that applications seem to have infinite flexibility. They execute smooth stepless control with great speed and absence of noise, vibration or inertia effects. They have won the respect of instrument engineers and process engineers alike as reliable and practical industrial tools.

The inception of electronics into process instrumentation, among other things, made the position of many existing electrical measurements more secure. It provided the means whereby certain measurements could be accomplished more accurately and by entirely automatic, continuous means. It provided new forms of primary measuring elements and new forms of measuring circuits which gave rise to the redesign of existing primary elements. These devices, coupled with improved motors, provided new methods of indicating and recording, while making possible the design of simplified and more flexible automatic-control systems.

*Substance of a paper presented at the National Electronics Conference, Chicago, Oct. 5-7, 1944. Re-written in large part for publication in *Instruments*.

HYDROGEN-ION CONCENTRATION MEASUREMENT

One of the early applications of electronics was an apparatus for measuring the potentials produced by the dissociation of acids or bases, and known as a pH or hydrogen-ion concentration meter. In early pH measuring assemblies using electrodes of hydrogen gas, antimony or quinhydrone, the potentials produced could be measured with conventional forms of potentiometers.

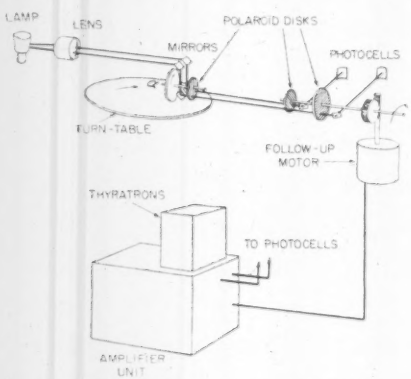


Fig. 1. Schematic diagram of Polaroid follow-up system.

These assemblies do not, however, lend themselves easily to continuous measurement and are, therefore, usually restricted to sampling techniques and used in conjunction with manually-balanced potentiometers. The growing recognition of the importance of pH measurement created a need for an electrode suitable for continuous measurement in all ranges of pH and non-poisoning in oxidizing or reducing solutions. This need led to the development of the glass electrode. The high electrical resistance of the glass electrode, however, is such that even the best galvanometers have insufficient sensitivity except when used with specially-prepared low-resistance glass electrodes.

Finally, the FP-54, a low-grid-current type of electron tube, was developed and applied to measure the variable-light characteristic of distant stars. With this tube, it became possible to amplify the glass electrode output to a level sufficient for operating more or less conventional forms of automatic potentiometers, thus making the continuous measurement of pH and subsequent automatic control practical. Automatic systems of this type are being used in the manufacture of penicillin.

RECORDING SPECTROPHOTOMETER

Visual color comparison of an unknown color with a standard, either with or without the aid of a colorimeter, is subject to uncertainties because the human eye is the final judge and because color standards, no matter how well they are preserved and guarded, will vary appreciably with time. The recording spectrophotometer[1] produces by means of an electronic method a permanent color record that is not open to dispute and is adopted by the American Standards Association as the fundamental measurement of color. Color matches, so important in paints, printed matter, plastics and textiles, obtained with this instrument are identical under all types of illumination—this not being the case with visual measurements made under varying light conditions. Furthermore, the spectrophotometer by use of an electronically-commanded servomechanism, automatically draws a color curve in not more than 5 minutes—in most cases in 2½ minutes—as compared to hours required for visual measurements.

TORQUE AMPLIFIERS

Electronics has made possible a wide variety of servomechanisms or follow-up systems which will amplify small torques so that the motion of a heavily loaded output drive shaft will correspond accurately in position and or speed with a low-torque input shaft without imposing any error-producing restraint upon its motion or reactive effort upon the input signal either in the direction of its rotation or axially.

Unique among them and designed for high-precision requirements is the polarized-light servo system shown in Fig. 1. It is being used in connection with a new electromechanical instrument for accurately solving problems involving integrations. It may also be used for accurate measurement of rotating-machine speed over a wide range.

GAS ANALYSIS

The coming of electronics has made possible an entirely new principle of gas analysis and, for the existing analysis techniques, it has provided a means for obtaining accuracy, and precision while providing automatization of the measurements.

The new type of instrument is known as the mass spectrometer. It includes a tube in which the gas to be analyzed is ionized by means of an electron beam in a partial vacuum. An accelerating potential propels the resulting charged

[1] [General Electric Co.] Autographic Color Analyzer. *Instruments*, Vol. 9, 1936, page 6

...s into a uniform transverse magnetic field which forces the ions to travel in arcs whose radii are proportional to $\sqrt{mv}$). By adjusting either the accelerating voltage or the magnetic field, each beam of ions of one particular mass may in turn be brought to focus at the spectrometer target. At the target the ions give up their electric charges, permitting exact quantitative measurements of the abundance of each particular ion to be made. These currents are one means by which the complex molecular structures of synthetics are studied. In general, the mass spectrometer would not be possible were it not for the stable electronic current and voltage regulators and the direct-coupled d-c. low-current amplifiers used in the beam-measuring circuit.

Noteworthy among the other gas analysis methods are absorption in the infrared and the ultraviolet, and thermal conductivity, while an interesting newcomer operates on the principle of density variation.

If you were to inhale a quantity of helium, your voice would take on a definite feminine and nasal quality; and would return stepwise to normal with each expiration—much to your relief. Use is made of this phenomenon in detecting density changes in a gas whose constituents are known. This is accomplished by resonating a sample of the mixture and recording the resonant frequency. Any subsequent change in molecular weight or density will produce an effect which can be measured either as a new resonant frequency or a phase shift in the oscillating energy. The gas column is force-driven by an electronic audio-frequency oscillator and the frequency at resonance, or the phase shift, is measured electronically. Through the use of this method, explosive mixtures may be avoided in the operation of hydrogen-cooled alternators.

These examples illustrate to some extent the versatility of electronic devices. The new instrumentation applications already mentioned — and a host of others—have earned a notable record of successful accomplishments and established a secure position for electronics in the instrument field. They are making possible new methods of processing and the production of new materials. Consequently, the process engineer has become receptive to the possibility of using electronic devices to measure and control the more common process variables: pressure, temperature, flow, and liquid level. Since none of these major process variables is in itself an electrical affect, and since electron tubes require electrical inputs, it is necessary to convert each process variable into an electrical actuating signal.

PRESSURE

In industry, pressures are indicated, recorded, and controlled almost exclusively by direct mechanical, pneumatic or hydraulic means, all of which provide high available output forces. The primary elements are simple, self-contained, low-cost devices. Remote measurement and control is obtained by the use of a single connecting tube when the required distance does not create objectionable complications.

Although there are a variety of methods for converting pressure effects to electrical signals in a satisfactory manner, there has been in the past little need for doing so except in special cases. The pressure in the process can by means of a single connecting tube be conveyed to a pressure-responsive mechanism and produce sufficient torque to operate a recording pen and an automatic-control mechanism. The advantages of such direct-measurement devices are:

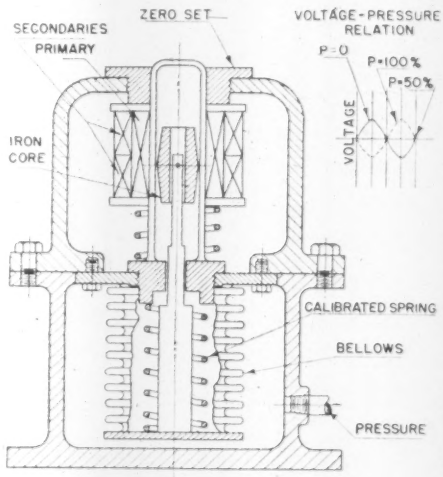


Fig. 2. Transmitter which converts pressure changes into inductance changes.

1. High available torque.
2. Completely self-contained.
3. Simple connection to the process equipment.
4. Economical simplicity.

There are, however, several reasons why electrical types of primary elements are useful:

1. Where the distances are great and the resulting transfer lags of pneumatic or hydraulic systems are objective.
2. Where it is hazardous to have the processed materials piped from the process apparatus to the instrument room.
3. Where pressures at a plurality of pressure points are to be measured by a single indicator or recorder.
4. Where dynamic pressure fluctuations must be measured and recorded.
5. For vacuum process control.
6. Where strip-chart recording is desired.

Industrial process pressures are usually measured by one of three methods:

1. By balancing the unknown pressure against a known force.
2. By measuring the deformation of an elastic member.
3. By utilizing a quantitative change in a physical property of a material.

The first method is represented by such devices as liquid-column manometers of the U and well types. These gravimetric instruments leave little to be desired. Tuned-grid-tuned-plate oscillator type relays are employed in connection with these gages, utilizing variation of the dielectric constant of the medium in the gage tube for control purposes. Electronic relay devices are also available which operate when the input contacts are bridged by a material having a resistance in the range of 0-5 megohms. Contacts sealed through the manometer wall are bridged by the partly conducting manometric fluid to cause relay actuation. Either of these types of electrical devices may be used with an electronic relay to operate an on-off type of automatic controller.

The second method of pressure measurement involves deformation of an elastic member and is by far the most common form in industry. Bourdon tubes, metallic and rubber-like diaphragms, and metallic bellows are examples.

Springs and spring-like materials making up these primary elements are subject to errors arising from hysteresis effects, changes in modulus of elasticity with temperature, and others. By limiting the deflections to 10% of the bellows length, the response can be made substantially linear. With electric gages, small linear dimensional changes representing a fraction of this percent deflection may be measured.

Fig. 2 shows how an iron core attached to the free end of an elastic bellows may be used to unbalance the inductances in an associated electric circuit. Properly designed circuits cause an a-c. voltage of chosen frequency to vary in amplitude and phase with the applied pressure. The electrical output may be fed to a demodulator (detector or rectifier) whose output operates a d-c. zero-center instrument, or directly into a phase-responsive instrument (wattmeter) or, if higher levels are required, to an electronic amplifier, with means provided in the output stage for actuating suitable indicators, relays, etc.

Converting the process pressure to an electrical signal provides (with suitable electronic devices) operating possibilities not afforded by direct-measurement methods; one illustration of this is the switching of a plurality of primary elements into a single indicating receiver, with considerable saving of panel space. In addition, the electrical method offers great ease in interchanging pressure ranges. The transmission distance is of course no problem for electrical methods.

The third pressure-measuring method is based on primary elements which exhibit changes in physical properties as a function of pressure loading. Owing to the negligible deformation they undergo, they may be considered force-measuring primary elements.

The piezoelectric effect is displayed by crystals such as quartz, Rochelle salts and tourmaline, which develop voltages when subjected to pressures. When they are compressed or otherwise stressed, electric charges appear on opposite faces of the crystal. The voltage

developed is proportional to the applied pressure and ranges from millivolts for quartz to volts for Rochelle salts (within reasonable temperature limits).

Magnetostriction is the magnetic equivalent of the piezoelectric effect. A force of compression applied to the end of a rod of Monel, nickel, stainless steel or similar materials will result in a change of magnetic permeability. If a coil surrounding the rod is energized by direct current, the effect of applied pressure may be observed on a fluxmeter. If the coil carries an alternating magnetizing current, the resulting change in reactance with compression may range from 5 to 20%. Both types find their greatest usefulness when coupled with electronic amplifiers and oscillographs for dynamic pressure studies.

Increased activity in low-vacuum processing, as in desiccation of blood plasma, production of penicillin and insulin, vacuum sputtering and the making of non-reflecting lens surfaces has placed new emphasis on obtaining instruments for vacuum measurement and control.

For low-vacuum processes, thermal-conductivity primary elements are used. They produce electrical signals, which are fed to electronic relays which in turn operate control mechanisms. Pressure controllers of this type are used in connection with power generating equipment for the primary processing of aluminum and magnesium ores.

A truly electronic instrument — the ionization gage — is used to measure vacuums of higher order. The atmosphere of the process is ionized by an electron stream in this gage, and the number of positive ions formed by collisions between a given electron current and the gas molecules is a function of the pressure. This positive ion current may be measured with a sensitive microammeter or vacuum-tube voltmeter, to obtain pressure readings.

It is not improbable that a pressure-responsive element like a spring-loaded bellows or diaphragm might be incorporated in an electron tube to modify the plate-to-grid-to-cathode spacing and provide an electrical output proportional to pressure. In effect, such a tube has been constructed and affectionately christened a Wiggletron.

FLOW

Flow is one of the most important of the process variables. Flowmeters are used to measure and control the ratios of materials supplied to a complex continuous process and are also used to determine accurately the quantities of a product delivered as a means of establishing costs. Flow quantities can be measured by volumetric and other positive meters, but flow rates are commonly measured by inferential meters employing primary elements such as orifices, Venturi tubes and flow nozzles. The rate of flow through such a primary element is proportional to the square root of the differential pressure across it. The pressure differential is usually measured by a manometer. Recording is often accomplished by placing on the surface of the manometric fluid a float which may then drive a pen across a chart. These flow elements introduce pressure drops which, like shunts in a bus bar, should be kept at a minimum consistent with the desired measurement function.

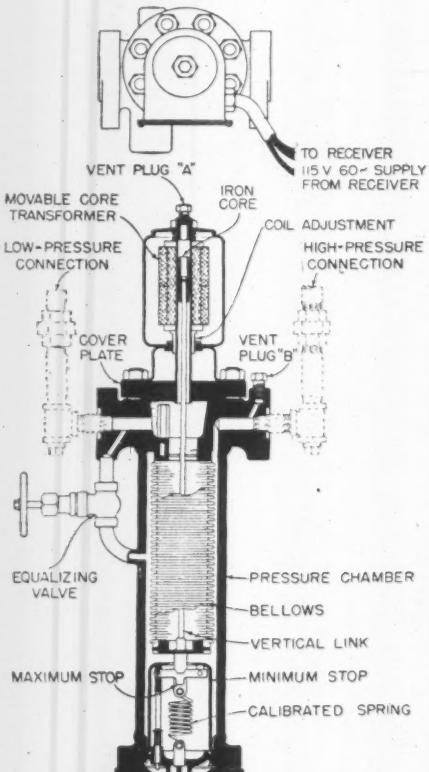


Fig. 3. Transmitter which converts differential-pressure changes into inductance changes.

In most industrial plants it is desirable to install the flow recorders on the main instrument board along with other process instruments. To do this with the mechanical type flow recorder presents some real installation difficulties. First, it becomes necessary to run two pipes (not capillaries) between the primary element and the recorder. Because these pipes open directly into the process apparatus, several precautions must be observed. The recorder should as a rule be located above the primary element so that process material or condensate cannot alter the effective head at the manometer. In the case of steam, condensation chambers must be provided and a series of equalizing valves must be installed at the manometer. One of the real hazards of this type of recorder lies in the fact that the instrument, usually containing mercury, is at process pressure and must be capable of withstanding pressure surges. This not only requires protection for the operator but also precaution against changing the zero by expelling mercury. Because the accuracy of square-root compensation depends on maintaining a real zero, care must be exercised also in leveling the recorder.

To this picture, the electronic method has much to contribute. The pressure differential at the constriction may be measured by a bellows type of differential-pressure-measuring element as shown in Fig. 3. The motion of the bellows' free end may be used to alter the inductive relation in a movable-core transformer. The resulting signal may then be transmitted over a pair of wires to an electronic servomechanism. The servomotor may be equipped with a cam for extracting the square root to produce linear recording and desirable control functions. This combination mechanical-electrical-electronic method of flow measurement is free of almost all the factors which plague the purely mechanical forms of flow indicators, recorders and controllers.

Another feature in favor of electronic instrumentation for flow is that it is better than other methods in meeting the common requirement of integrating the total flow through the primary element, or totalizing the outputs of a plurality of flow-measuring elements. Each electrical output may be recorded independently at as many points as desired, or series connected to produce a record of the total flow. Similarly, electronic flow instrumentation facilitates recording of differences in flow between two flow elements.

TEMPERATURE

Unlike pressure, temperature cannot be measured directly but must be inferred from one of its observable effects. So many of these observable effects are exactly known that small-type lists of classes of temperature-measurement methods (not including varieties of instruments) fill several pages in a recent book.* Before the coming of electronics, numerous satisfactory instruments for *indicating* industrial process temperatures had been developed. Therefore, it is especially in the rapid *recording* and close *control* of process temperatures that electronics has made great contributions. But electronics has even made possible new types of primary temperature-measuring elements.

[Editor's note: An ordinary gas-filled triode, sensitive to ambient temperature, may be said to represent a new type of thermometer!—MFB]

Among the older types of primary elements, those utilizing electrical effects are obviously the most suitable for use with electronic amplifiers and electronic servomechanisms. Thermoelectric and resistance-thermometric primary elements are particularly useful in this respect.

Thermocouples are available in numerous combinations of materials for temperatures from –200°C. to 1450°C.

*American Institute of Physics Temperature Symposium. Reinhold Publ. Corp., New York, 1941. Pages 344-352.

are for most industrial furnace atmospheres. The e.m.f. output is relatively weak: a 1°C. change in a controlled temperature appears as an e.m.f. change of the order of microvolts, so that electronic self-balancing potentiometers (described below) are winning ready acceptance. In certain applications, fine-wire couples can be used bare; and their nearly instantaneous response to temperature changes is another reason for using this class of primary elements in conjunction with electronic instruments.

Similar considerations apply to resistance-type primary elements. The chief difference is that the temperature effect being a resistance change, the measuring circuit must be a bridge. Most self-balancing instruments, however, can be converted from potentiometers to bridges or vice versa.

For measuring temperatures higher than the practical limits of thermocouple ranges, use is made of radiation and optical methods. These methods have no upper limits other than the upper limits of the calibrated ranges of the instruments themselves, since no part of the instrument need come into contact with the measured source.

Total-radiation pyrometers may be used for measuring "low" and "medium" as well as "high" temperatures, but they are usually designed and calibrated for temperatures above "dark red" (about 550°C.) because the radiant flux from a source to a receiver varies as the fourth power of the temperature difference between source and receiver. There are numerous types of total-radiation pyrometers but the most widely used industrial forms are those employing blackened thermoelectric elements (single couples or thermopiles) as the radiation receivers. The output of these primary elements is, of course, an e.m.f. which can conveniently be fed to an electronic device. A useful type of receiver is a vacuum thermocouple, in which the thermojunction takes the form of an extremely thin ribbon mounted between two heavy supports which serve both as the lead wires and as the cold junctions or the single thermocouple. The ribbon is only 2 mm. wide and the "hot junction" proper is a weld line across it. For about 1 mm. on each side of this junction the ribbon is blackened, thus providing a radiation-receiving area 2 × 2 mm. The thickness of the ribbon being about one micron, the volume of the radiation-sensitive portion is about 0.004 mm.^{3} and its weight is about 0.003 mg., thereby providing exceptionally fast response. For example, when primary elements of this type are used in conjunction with high-speed electronic instruments, it is possible to record the temperature gradients along the length of rapidly-moving objects such as rails or billets on a rolling-mill stand.

For very high temperatures, there are also photoelectric pyrometers which measure the energy in a narrow band of wave-lengths radiated by the hot body. These photoelectric instruments represent an attempt to automatize the familiar optical pyrometer. Another photoelectric pyrometer utilizes the two-color method of temperature measurement. It embodies two color filters (red and green) two phototubes, and an electronic amplifier. By measuring the red-green ratio the temperature may be directly determined. The extremely fast response of photoelectric devices being well-known to *Instruments* readers, there is no need of elaborating upon this advantage.

There are various industrial temperature problems for which high-speed electronic measuring circuits have been devised. These are not only rapid in operation but suitable for application under adverse conditions of off-level and vibration.

PRIMARY ELEMENT DETERMINES CHOICE OF CIRCUIT

The common denominator of all measurement of non-electrical variables by electrical methods is the fact that the primary element will yield only a-c. or d-c. Thus, there need be only two types of measuring circuits for all these variables.

A measuring circuit for use with d-c.-output primary elements is in general of the potentiometer type, instead of a simple two-wire connection to a direct-deflection indicating instrument. This choice is based largely on the accuracy requirements established by the industry.

Although negative or inverse feedback has done much to make the amplifier a measuring tool of permanent calibration, electronic circuits are not used extensively for quantitative measurement and control in the process industry. This is no reflection on the electronic engineer but is a situation brought about by the chosen requirements in industrial automatic-control functions. In this respect, amplifiers are used more often as relays or unbalance detectors, that is, as a servo system component.

A measuring circuit, to be useful for the more complex forms of automatic control, must not only perform the function of rebalancing itself in accordance with process variable changes,

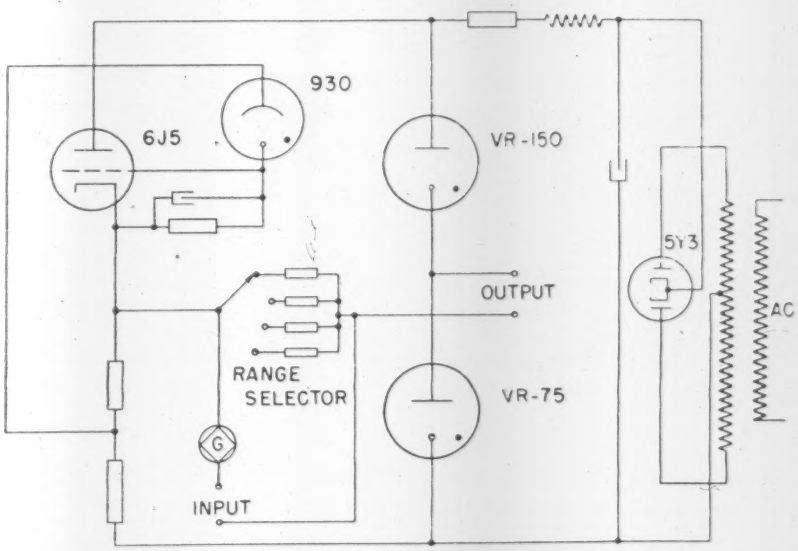


Fig. 4. Circuit diagram of photoelectrically-balanced potentiometer.

but must also be capable of initiating a series of operations of the process apparatus which will return the process variable to its control setting.

SELF-BALANCING POTENTIOMETERS

While there are a variety of electronic types of self-balancing potentiometers, when analyzed they represent two major principles: (1) those which feed back electrically and negatively a portion of the amplifier output to reduce continuously the input signal to a predesigned minimum in keeping with the range of the primary measuring element; and (2) those which amplify an unbalance signal and control power flow to drive a rebalancing motor in such direction as to reduce the input signal to a predesigned minimum determined by the sensitivity of the system.

Photoelectric Potentiometer. — The photoelectric potentiometer using a reflecting type galvanometer and phototube combination is typical of the first class. The signal deflects the galvanometer, causing a light beam to strike the photosensitive surface and thereby control the grid potential of an electron tube. The tube may be used as a variable resistor in one arm of a Wheatstone bridge as shown in Fig. 4. The grid signal causes an unbalance of the bridge, with a resultant undirectional output current. In series with the load is a resistor so arranged that a voltage

proportional to output current is fed back in opposition to the input voltage. This causes the galvanometer to take up a stable position as some function of the remaining unbalance current. This current is not constant but varies with the primary-element sensitivity, the kind of optical system and the input voltage. How nearly this approaches a true potentiometric measurement depends upon the galvanometer sensitivity.

High sensitivity may be realized by using a slightly under-compensated galvanometer as the basic measuring element. By compensating the wind-up torque of the suspension, one does not sacrifice sturdiness and gains in sensitivity. If the torque were completely compensated, this basic measuring element would have an "infinite" deflection for "infinitely small" signals, and it would then be a true fluxmeter. However, for practical reasons, this state is not achieved, but the result is a sturdy portable electronic d-c. potentiometer having a sensitivity many time that of other types. The high sensitivity of the basic element simplifies the optical system required.

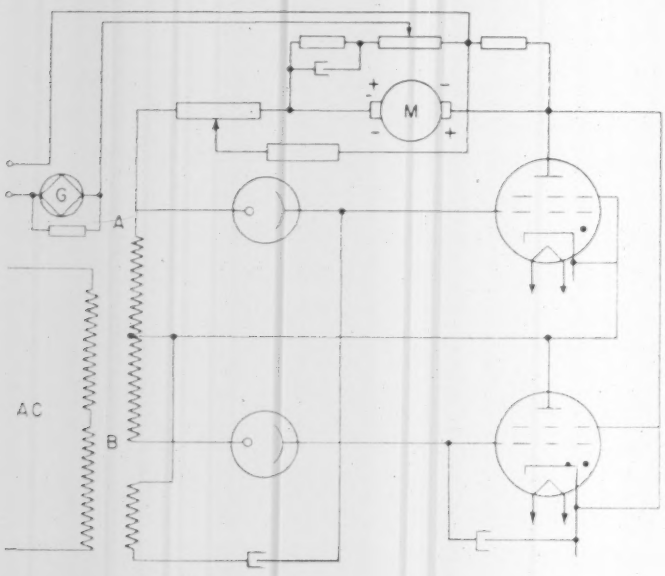


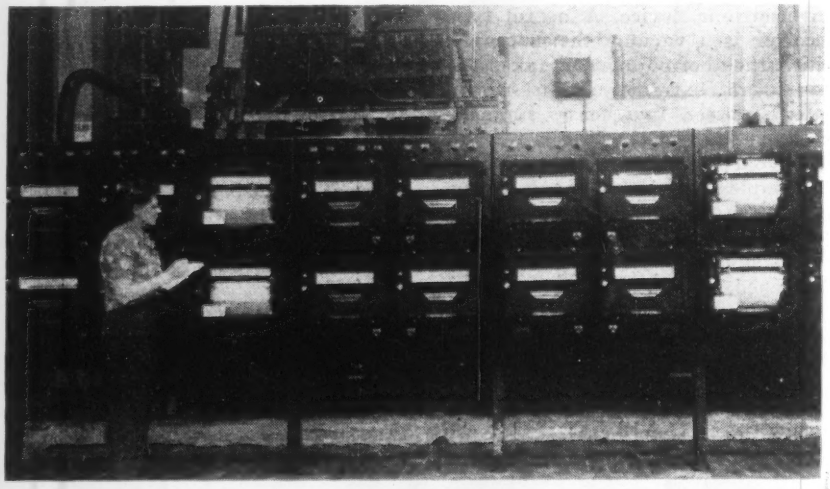
Fig. 5. Circuit diagram of photoelectrically-balanced potentiometer or photoelectrically-piloted control system.

As shown in Fig. 5, the galvanometer may actuate either of two phototubes to control a pair of thyratrons connected back-to-back to produce d-c. output in either direction. The output of such a potentiometer may have for its load a recorder, a relay, a solenoid valve, a small motor, a generator field or a saturable reactor. It is recognized that these potentiometers characterized by high sensitivity and high gain have limited control ability. A prerequisite for a potentiometer is that it must have sufficient speed and output torque to operate any of the common control mechanisms.

Electronic Potentiometers.—Another class of potentiometers comprises those used as unbalance detectors utilizing an electromechanical type of feedback to rebalance the input signal to a minimum in keeping with the overall sensitivity of the system. This class of potentiometer is the most useful for automatic-control applications. It may be divided into two types, which may be termed "continuous" and "discontinuous." *Continued on page 155*

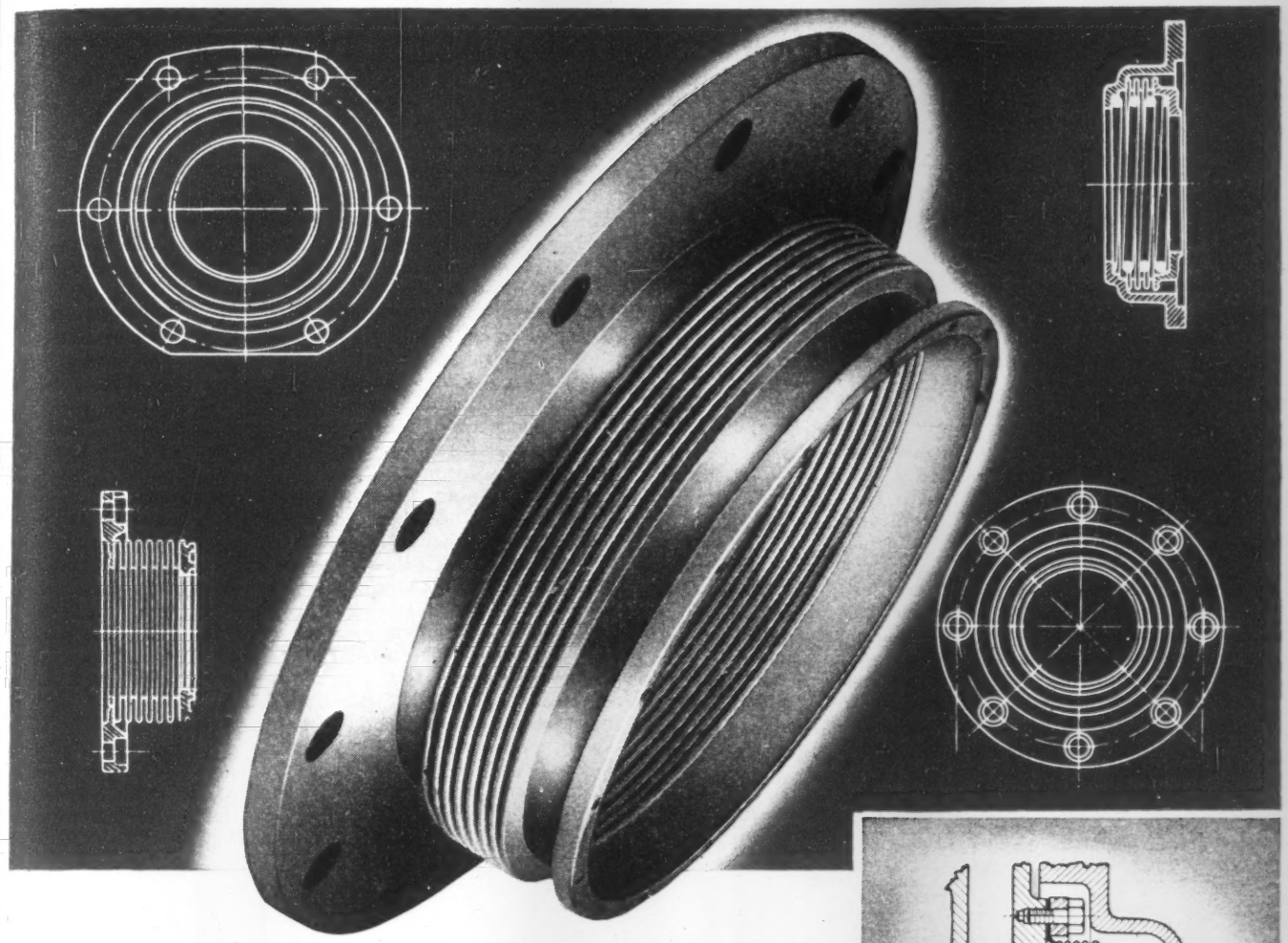
Cover Picture Story*

A woman "instrument man" was snapped by an Alcoa photographer as she was measuring the temperature of an aluminum ingot at the new McCook (Ill.) plant of the Aluminum Company of America. Another is seen at the central control board in the adjoining photograph. The Instrument Department, headed by W. J. Huffstettler, comprises fifteen men and two women, all of whom had received specific training for the McCook plant's instrument work. When the plant was started, a special 36-hour training course was conducted for them by the Brown Instrument Co.'s Chicago office: 3-hour classroom sessions twice a week on theory and operation of instruments; and 3-hour laboratory-practice sessions once a week on making thermocouples, disassembling and reassembling instruments, etc. Previously, those who lacked electrical training had taken the 10-week full-time "Fundamentals of Electricity" course conducted by Educational Supervisor Mehegan in order to qualify for the Instrument Department.

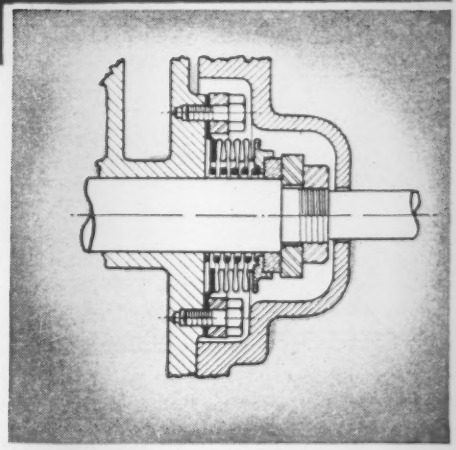


The new McCook plant makes the aluminum-sheet "skins" for war aircraft. Its instrumentation, according to L. Morton Morley of the Brown Instrument Co., comprises more than 400 Brown recording and control instruments. "While the majority of the instruments are used for conventional applications," he stated, "the electronic instruments are being used for measuring and close control of specific temperatures . . . installed at three different processing points, for in each of the three operations temperature must be taken at extremely high speed."

*The courtesy of the Aluminum Company of America is gratefully acknowledged; as is the receipt of material from the following in the Brown Instrument Company: L. M. MORLEY, V-P.&GSM., Philadelphia; R. A. WEIKEL, Branch Mgr., Pittsburgh; J. A. ROBINSON, Industrial Mgr., Chicago; also H. CABOT, Carl Byoir & Assoc., New York. Circumstances made it necessary for me to use only fragments of the text-matter supplied, and to condense drastically. A full-length technical article may appear later. —M. F. BEHAR, Ed., *Instruments*.



Now the WHOLE doughnut goes to work



WHEREVER there's danger of leakage of gas or liquid around a rotating shaft, there's need for a Sylphon Shaft Seal. Principles successfully applied to control problems for more than 40 years, have proved eye openers in this special field.

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Sylphon Shaft Seals are engineered for each specific application. Sizes range from seals for tiny instrument shafts to seals for huge military installations. Finely machined and balanced, they afford a perfect seal against pressures up to hundreds of pounds, operate at shaft speeds up to 400 RPM.

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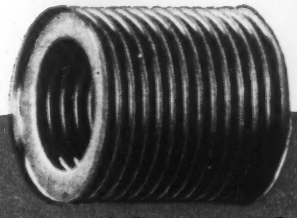
FULTON SYLPHON



TEMPERATURE CONTROLS

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ELECTRIC GAGING METHODS
for Strain, Movement, Pressure and Vibration

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VII. PIEZOELECTRIC GAGING METHODS.

§ 1. General.

It is characteristic of many asymmetrical crystalline materials that if their dimensions are changed through the application of mechanical force, electric potentials will appear upon certain surfaces of the crystal. Such materials are termed piezoelectric, and the most widely known are quartz, tourmaline, and Rochelle salt (potassium sodium tartrate).

Many other crystalline materials possess the property to a greater or less degree, but only in the case of tartaric acid, sucrose (cane sugar), and a few sodium and potassium salts is it of sufficient magnitude and uniformity to justify its application in measurement.

The piezoelectric property is associated with the crystalline structure of the material* and, as might be expected, is effective only for certain directions of application of force; if the force be applied at an oblique angle there will in general be a component effective in the proper direction. For use, rectangular plates or wafers are cut from the mother quartz in such a manner as to permit the application of the force to the flat surfaces of the wafer. Thus the crystal may be made capable of withstanding the greatest mechanical load.

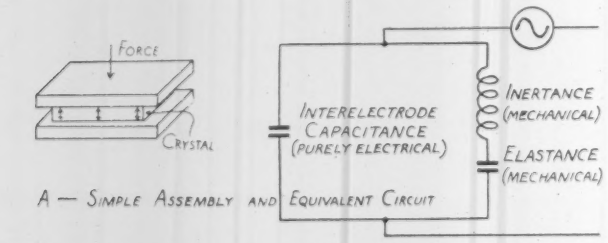

FIG. 116

Flat metallic electrodes are used as collectors of the electric charges produced, and the entire assembly of crystal element and electrodes may be said to behave in the electric circuit as a capacitance—or a capacitance in series with a generator having negligible impedance—so that the piezoelectric unit has an impedance increasing as the frequencies involved decrease. (Strictly speaking, even the simplest assembly is not a pure capacitance by reason of the crystal's mechanical properties. The equivalent circuit usually drawn to explain the "time-keeping" properties of the device as a generator of constant frequency is shown in Fig. 116A. It should be noted, however, that when a piezoelectric element is used as a generator of constant frequency it is operated in a condition of mechanical resonance, while when it is used to convert mechanical force to electrical energy it is operated well away from its natural frequency.)

The most commonly used piezoelectric material for mechanical measurements is quartz.† Quartz has the important advantages of high mechanical strength and resistance to both heat and moisture. Tourmaline, which also possesses these advantages, is quite costly because it is considered a gem. The organic piezoelectric materials—Rochelle salt, tartaric acid, and others—although much more sensitive, have much lower mechanical strength, cannot stand the high temperatures of many applications, and are impaired by moisture.

Quartz crystals for mechanical measurements are ordinarily cut so that the force may be applied parallel to the electric axis; then the metallic electrodes through which the force is applied also collect the electric charges. The potentials developed on these electrodes are linearly proportional to the applied force. See Fig. 116A.

Rochelle salt crystals, because of their low mechanical strength, usually receive the applied force through some linkage which limits the mechanical stress developed in the crystal. In order to facilitate their installation and to increase the output, such elements are often composite, made up by cementing together slices of crystalline material with inserted foil electrodes. These composite elements may be either "bender" or "twister" elements, depending upon the manner of cutting the slices and their orientation when cemented. Single crystal elements, when used as motor elements rather than pick-ups, may be termed "expander" elements.[259] These three forms are illustrated, and their behavior indicated, in Fig. 116B. The composite elements are often known as "bimorph" elements.

Any of the four forms illustrated may be employed either to convert mechanical to electrical energy, or to convert electrical to mechanical energy.

§ 2. Application of Piezoelectric Crystals.

The most direct mode of application of a piezoelectric crystal is in the measurement of mechanical force applied to the crystal itself. The crystal element and electrode assembly of Fig. 116A may be used to measure force, if it is placed mechanically in series with the applied force and the load. One electrode must be insulated.

It is possible also to measure strain in a mechanical member by attaching to it a crystal, so that the strain in the material of the member is imparted to the piezoelectric material. For this application, the crystal element may be cut at an angle of 90° to the electric axis; then a change of length of the crystal element will develop electric charges on opposite flat faces. This is illustrated in Fig. 117, in which the direction of the electric axis of the piezoelectric material is indicated by the small arrows. Crystal elements cut in this manner have been used for measurement of dynamic strains at high rates. Some have been applied to the surface of a stressed member with an adhesive, as indicated in Fig. 117; in measurements of internal stresses produced during the driving of reinforced concrete piles crystals have been enclosed in capsules which were then

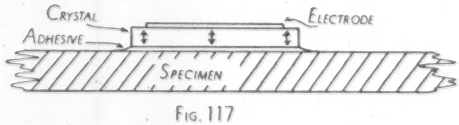

FIG. 117

*Quartz crystals, for example, are trigonal, six-sided prisms with pyramidal ends. A crystal has one axis of three-fold symmetry (the optic or *Z*-axis) and three two-fold axes (the electric or *X*-axes). Owing to the imperfect form of crystals as found in nature, the axes are located by optical means.

This relation between electrical, optical, and mechanical properties imposes certain limitations on the use of piezoelectric materials. For example, quartz is unsuitable for use as an element for direct measurement of hydrostatic pressure, because equal and opposite charges are produced along pairs of electric axes, and these counteract each other. This difficulty does not appear with tourmaline, which has a different crystal structure.

†Excluding, perhaps, the special application of the Rochelle-salt crystal in vibration pick-ups.

(259) Ben Baumzweiger. Application of Piezoelectric Vibration Pick-ups. *Journal of the Acoustical Society of America*, Vol. 12, 1940, pages 303-307.

...ded within the concrete.[260] These crystals were cut in ...ismoidal form, with the length perpendicular to both the ...ptic and the electric axes. The electrodes were applied to ... sides of the crystal, and the force, through a spring ass...bly, to the ends. Most of the mechanical load was ca...d by the metallic capsule. This mechanical construc-

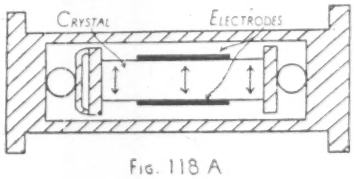

FIG. 118 A

...shown in Fig. 118A, is applicable to many other uses. It ..., however, deficient in resistance to vibration disturbances: the relatively large mass of the crystal element permit the development of acceleration forces great enough to produce spurious response under some circumstances.

Crystals of tourmaline, sugar, tartaric acid, and other materials have been applied to the measurement of hydrostatic pressures directly.[261] They must be fitted with metallic electrodes and suitably insulated electrically; if the crystal element is encased in a flexible oil-filled capsule the required electrical insulation is afforded while at the same time the crystalline material is protected from contact with the water.

The direct application of the piezoelectric crystal, as described above, is much less common than its use in a mechanical device or fitting which converts the magnitude being measured into a force which is then applied to the crystal assembly.* Mechanical "harnesses" of this sort offer several advantages: they can provide greater sensitivity by employing more crystal elements; they can isolate the crystal elements from damaging heat and moisture; they can convert other magnitudes into force, which the crystal element can measure; and they can act as safety devices by limiting the force which can be applied to the crystal element. They also make possible another range of measurement: since it is not convenient to apply tensile force to a crystal element, by polarizing it initially with a compressive force the measurement of tensile forces or of pressures below atmospheric is made possible. In the converse application—when the crystal is used as a motor or driving element — the use of composite elements and mechanical linkages makes possible a number of useful applications otherwise unavailable.

Continued on Page 168

(260) G. Grime. The Measurement of Impact Stresses in Concrete. *Proceedings of the Physical Society* (London), Vol. 46, 1934, pages 196-204.

(261) A. W. Lawson and P. H. Miller, Jr. Piezometer for Transient Pressures. *Review of Scientific Instruments*, Vol. 13, 1942, pages 297-298.

*In this treatment the use of special mounting methods to adjust the frequency of quartz resonators, and of special cuts to stabilize them, will not be discussed.

SIMPLE ADJUSTMENT PROCEDURES for Automatic Controllers of the Proportional Class

By EDMUND D. HAIGLER, Manager, Application Engineering Dep't, The Foxboro Co., Foxboro, Mass.

INDUSTRIAL control instruments are capital goods purchased to produce revenue. Obviously, they will be more attractive investments if their adjustment to revenue-producing operation requires a minimum of skilled attention or process disturbance.

This talk is to cover simple setting procedures for controllers of the proportional class. It will be based on pneumatic controllers, but much of what is said will apply also to electric and hydraulic instruments. While the immediate problem is adjustment, the remarks will be mainly about controllers and what they should do, because after that, there is so much less to say about adjustment.

1. "PROPORTIONAL"

The simple proportional controller can be applied to almost any continuous process—what we call the "shower-bath type" of process. Also it *may* be substituted for an on-off controller on a "bath-tub type" of process where on-off valve action is not permitted. The function of a proportional controller is simply to measure a deviation from the setting-point and change its control-valve position an amount proportional to the deviation—whence the name. The range of measurement over which the control mechanism functions is the proportional band or throttling range—usually expressed in percent of scale range for full valve travel.

The action of a proportional controller is very much like that of a "green" operator: If he makes too large a correction for a deviation, the process continues upset. If he makes too small a correction, the deviation continues on and on and he has to correct and correct again. He soon learns to make "proportional" corrections suitable to that particular process.

Similarly, if the controller is too active and overcorrects, causing the process to cycle, one must increase the proportional band or throttling range until process stability results. If the controller is too sluggish and allows the deviations to go a long way before being arrested, one must narrow the proportional band, in steps, until instability is reached or imminent, and then increase it somewhat, to give a margin of stability for changing operating conditions. This may seem a rather coarse adjustment. It is—and is so intended. Steps of 2:1 are reasonable for initial adjustment, and never less than 1½:1 at the end. Smaller steps simply are not significant in practical operations.

Under steady operating conditions, finer settings *are* possible, but such fine adjustments should not be attempted. Remember, process upsets do occur, and then the operator is busy and needs automatic assistance. On most processes, some variables are *not* automatically controlled and *they* need enough attention, without adding the controllers too. Remember, too, that process characteristics may change over an operating cycle or with large changes in load, especially when valve characteristics are unfavorable by reason of type of valve or insufficient pressure drop across it. Remember finally, that routine process maintenance may change process control characteristics. Automatic control should be truly automatic. It should take care of these normal events.

Looking at it another way, the industrial user buys an automatic controller because he expects it to show a profit as an investment—in most cases a relatively large profit. Usually the possibilities for a profit are far greater during short upset periods when good automatic control can more quickly stabilize the process and save waste or degraded product, than during long stable periods when finer adjustments are possible. Furthermore, with a good controller having a high force/friction ratio, and connected to a valve also with a high force/friction ratio, the difference in operation with somewhat wider than critical proportional band is often very difficult to detect.

Thus, in a *proportional controller*, simply set the proportional band by steps, wider for stability, narrower for activity. Do not set it too fine.

*Presented at the American Society of Mechanical Engineers' Symposium on Derivative Control Action, June 20, 1944, Pittsburgh, Pa.

2. "AUTOMATIC-RESET"

Naturally, the simple proportional controller has limitations. One of the most serious is drift of the control point with load. Since, with any given index setting, each valve position corresponds to a certain measurement value, a change in load always results in a new valve position at a corresponding reading. If the process is sluggish or erratic, demanding an unusually wide proportional band to prevent overcontrol and cycling, the drift of control point with load is large and troublesome. "Proportional reset" controllers were developed for such applications. Combined with the basic proportional-control mechanism is an automatic-reset mechanism, the function of which is to superpose on the proportional correction a reset correction which brings the control point back to the setting after an upset.

Returning to our manual operator (now becoming more experienced) we find that he is not merely arresting the deviations but is also making gradual corrections to bring the process back to the desired measurement. If he makes these manual "reset" corrections too suddenly, the process will be upset again. If, on the other hand, he makes the corrections *very very* gradually, it may take quite a while to get the measurement back where it should be. These effects are shown even more clearly if we give this operator a wide-band proportional controller with a second pen on the setting index. From such practical observations as well as from more theoretical studies, it is found that each process has a *characteristic recovery time*, and an attempt to reset in less time will upset it further. When the reset time of an instrument is set to this fastest stable recovery we call it "critical reset." It is found, also, that longer reset times, two, three, even *five times* the critical value, usually have little or no effect on economic operation of the process. This is explained by the averaging or "integrating" action of the reset system which operates to hold a precise average value of the controlled variable.

Thus in a *proportional reset controller*, first set a reset time *longer* than the recovery time of the process. In case of doubt go by experience with similar process units, by analogies on a new process, or simply set the longest reset time. Then find a suitable proportional-band or throttling-range setting, by steps, as before. If the record should show a long dragged-out recovery, after a single upset, or a wandering in normal operation, reduce the reset time in large steps, *without changing the proportional band*, until performance is satisfactory.

This is a simple procedure, but not a trial-and-error procedure. It gives directly an accurate — we might say measured — result for that particular process, and without disrupting operations. If any difficulty is encountered it is a warning to look for trouble, perhaps in the instrument; more likely in the valve, on which the stuffing box has not been lubricated or has been pulled up tight; or, even more likely, in the process, where erratic behavior is resulting from trouble or from primary variables not tied down by other controllers. In all such instances, controller adjustment is a compromise: difficult to make, chiefly because it is difficult to decide just what compromise best suits all conditions.

3. "DERIVATIVE."

Returning again to our operator (who by now is becoming considerably more skilled) we find that after a major process upset he may make a *temporary overcorrection*, which stops the deviation shorter and brings it back to the control point sooner. This is the "derivative correction," so called because it is made in accordance with the rate-of-change or derivative of the measurement. This correction is in the same direction as the proportional correction when the deviation is increasing, opposite when decreasing and zero when unchanging.

The behavior of an active derivative controller is not always easy to understand. Proportional action is easy to follow by itself, or even when combined with relatively slow automatic-reset action. When derivative action is added, the behavior of the output air pressure can be quite puzzling, unless one remembers that the two or three functions are going on simultaneously. One is likely to secure even less than the usual mediocre results from attempts to make settings by casual observation and tinkering. Nevertheless, if certain simple setting procedures are followed, it is easy to get adequate adjustments of derivative type instruments.

The proportional derivative controller is used on such batch processes as shredding of cellulose in the viscose process, where there is great energy storage on the supply side and little on the load side, or on batch reaction kettles where there is a relatively sudden exothermic or endothermic reaction. Also it may substitute sometimes for a proportional reset derivative controller on responsive continuous processes. On such processes a simple proportional controller is able to handle the process, except at the peak load or upset point, where a bad deviation or overshoot occurs unless very wide proportional bands are used with correspondingly large deviations. This suggests the use of derivative control, and gives the cue to its adjustment.

In a *proportional derivative controller*, first set the proportional band for

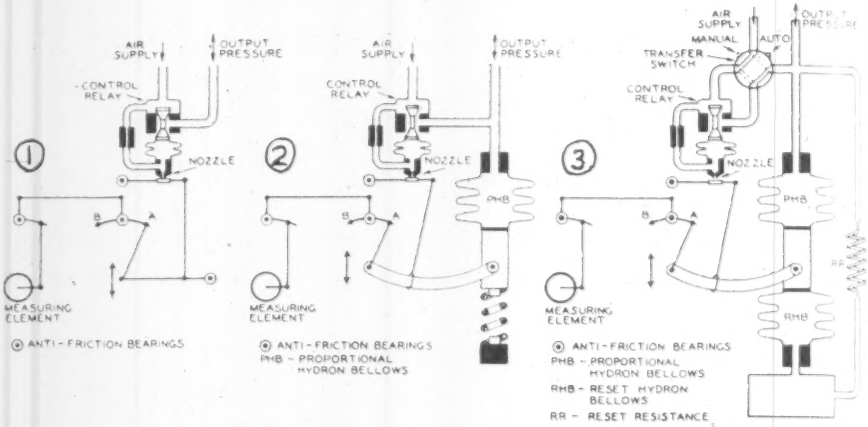

Fig. 1. The three principal classes of air-operated automatic-controller mechanisms, as exemplified in Foxboro Co. schematic diagrams.
(1) Mechanism providing on-and-off mode of control.
(2) Mechanism providing proportional-position mode of control.
(3) Mechanism providing proportional-reset mode of control.

4. "HYPER-RESET."

The proportional reset derivative controller has come into wide use. For many years Foxboro Stabilog Temperature Controllers were provided with some derivative effect by bringing the connection into the volume tank through a considerable length of capillary resistance, most of which was coiled up inside the tank. This resistance temporarily varies the effectiveness of the volume and thus results in a derivative effect. Recently Foxboro has made variable derivative action, or "Hyper-Reset" standard in Stabilog Temperature Controllers, utilizing a novel capillary resistance and capacitance network to provide a definite value of derivative time for each value of reset time without an additional adjustment. Other makers have offered derivative action with separate adjustment.

The adjustment of proportional reset derivative controllers would be very difficult were it not for the fact that there are optimum relations between derivative times and reset times, which

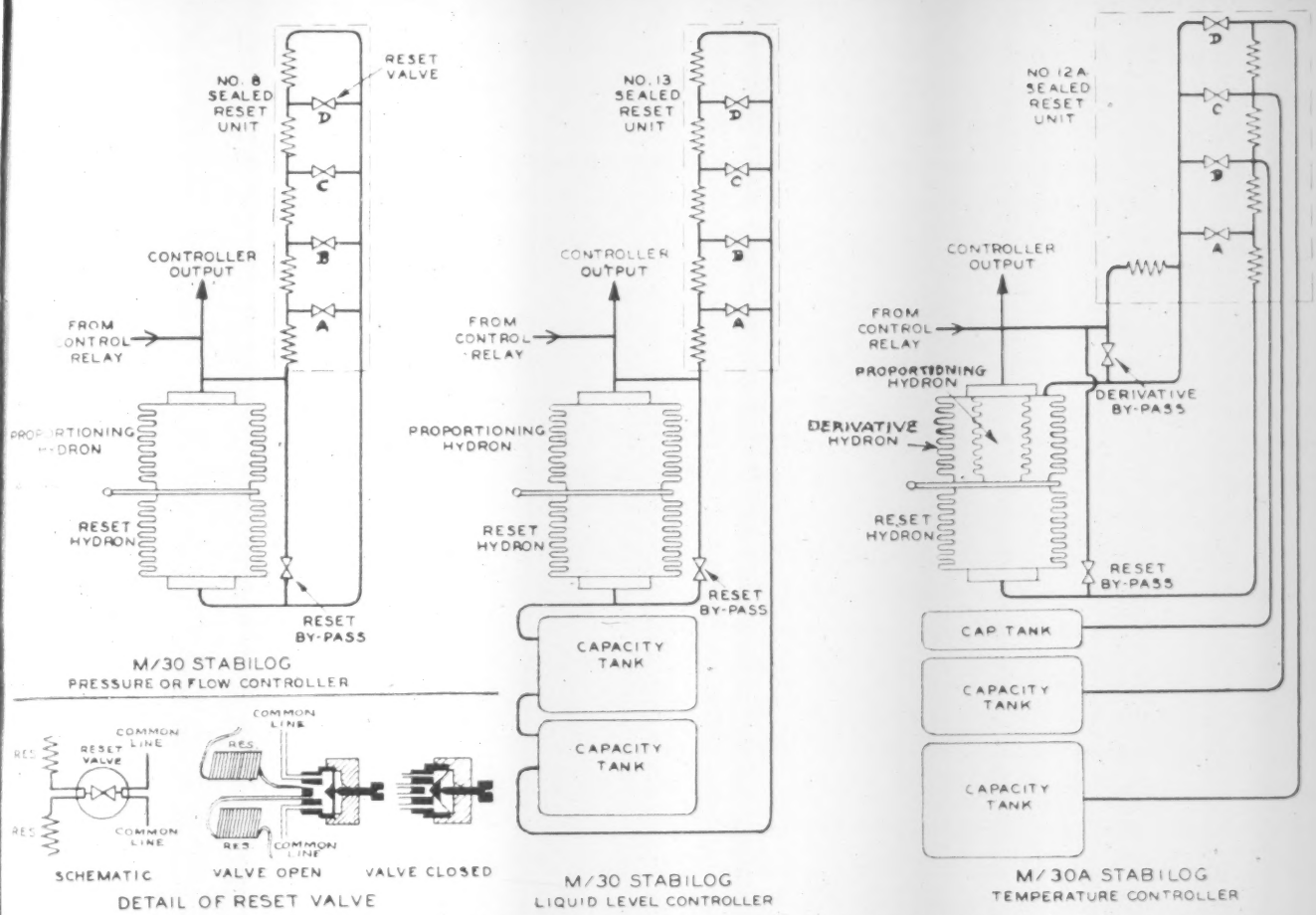

Fig. 2. Schematic diagrams of pneumatic circuit elements in three classes of Foxboro air-operated automatic controllers, showing the adjustment valves A, B, C and D to which Mr. Haigler refers in the last section of his article.

should not be exceeded for stability. This makes it possible either to scale the reset and derivative adjustments and then set them in definite relationship, or to build the relationship into the control system. However, because of significant variations in the construction of various proportional reset derivative instruments, varying recommendations may be made regarding derivative to reset time relationship and setting procedure.

In the Foxboro Hyper-Reset Stabilog Controller the adjustment procedure is as simple as that long used in proportional reset controllers. It is slightly modified to provide for the fact that cycling can be caused by excessively long derivative time, as well as by less-than-critical reset time. Fortunately, the identical adjustment procedure is equally suitable for the Stabilog without Hyper. Of course, with the reset adjustment made in only four large steps (or five in instruments without Hyper), and no separate derivative setting, the total number of adjustment combinations is already limited. Only a few of these need be tried, not by blind trial and error, but in a simple direct procedure, which *measures* process characteristics, yet avoids appreciable cycling or other upsets to process operation. Short cuts are possible through experience with similar process units or by analogy on a new process.

5. COMPLETE ADJUSTMENT PROCEDURE

In a *complete adjustment procedure*, first set the proportional band at 100% and open Reset Valve *C*, leaving all others closed. This is setting "100/*C*." (In the great majority of cases the process will control stably. If so, proceed; if not, skip to the next paragraph.) Reduce the proportional band in steps of 1:1½ until a tendency toward cycling is apparent, and then return one step. Next try *B* valve open, closing *C*. If unstable return to *C;* if stable try *A* valve open, closing *B*. If unstable return to *B*, but if stable leave on *A*.

If unstable at "100/*C*" try "100/0" (no valves open). If stable proceed as before, first to find a suitable proportional band, and then to try reset time *D*. If still unstable, there may be trouble in the process, or in the control system, especially a sticking valve. Occasionally the process may require extremely wide proportional bands and/or extremely long reset times, or even be inherently unsuited to this type of control.

In practice, this unabridged setting procedure is further short-cut by skipping settings outside the probable range. Many engineers almost always start with "60/*C*." Even where settings on similar process units are not known, or where analogy with a similar process is questionable, the reactions of *the particular process* on hand control, while it is being balanced out prior to setting the controller, are significant. If slight changes in output pressure cause considerable changes in measurement, a wide proportional band will be required for stability; conversely for narrow proportional band. Similarly, if the time for the process to level out or recover from upsets or to follow manual changes in output pressure is brief, a short reset time is permissible; conversely if the recovery time is long, a correspondingly long reset time is indicated.

6. CONCLUSION

In conclusion a few words of caution are in order. A lot of ground has been covered in these remarks and, in attempting to be brief, explanations have been abbreviated, and important qualifications or limitations contained in a few words. Furthermore, analogy from manual control has been used without detailing its limitations. However, it should be obvious that a controller, though very effective because continuously and minutely attentive and precisely repetitive in its response, is unreasoning. Hence it cannot be applied exactly like manual control. Probably the most striking example of this is the widely used on-off controller which does what is never attempted in manual control but, where applicable, can surpass any other type of control.

Simplified Orifice Design for Existing Pipe Lines in Industrial Plants

By D. M. YODER, Columbia Chemical Div., Pittsburgh Plate Glass Co., Barberton, O.

FROM time to time a number of articles on orifice design have appeared in *Instruments*. These articles for the most part have been written by engineers connected with companies engaged in the manufacture and sale of orifice type meters.

Many meters are used in measuring fluids, such as natural gas, sold to customers. Since the revenue from the fluid or the cost of the fluid (depending on which side of the fence you happen to be) is based on the meter reading, no expenditure for the best possible installation can be too great. It is of the greatest importance for the protection of both parties that the last word in accuracy be incorporated in the design of the meter. It is natural, then, that the manufacturer of those instruments should be extremely interested in designing orifice installations with the highest degree of accuracy possible.

The instrument engineer in industry, however, faces an entirely different problem. With him it usually is a compromise between accuracy and cost of installation with cost of installation often on the winning side. The meter installation in which he is most interested in accuracy is possibly the steam generation from the boilers. But even here, relative accuracy of a fairly high degree is all that is necessary as the relative efficiency of the boilers from month to month can be determined just as accurately with the less accurate as with the more accurate meter.

Most other installations are either for distribution of fluids to various departments, or for aiding the operator in the operation of a process. In neither case is extreme accuracy required.

A great majority of orifice installations in industry of which the author has had experience or knowledge are in OLD PIPE LINES. It is quite often desirable to know the approximate flow of fluid through a given line and worth a certain amount of money to management to get it. However, it may not be worth the cost of installing a new line or even of installing a new flange in order to get a good orifice installation. The smaller expense of using an existing flange in an old line, to get an approximate flow, may be justified. It is apparent, in this case, that an extremely accurate orifice is not justified, as the error due to faulty installation may be five times as great as a less accurate orifice.

It seems to the author that there is a field for a simplified orifice design which, although not the last word in accuracy, will be sufficiently accurate for most industrial purposes.

Let us take the hydraulic formula:

$$W = \frac{7.22\,C\,A\,S_t[2gh(S-S_t)/S_t]^{1/2}}{(R^4-1)^{1/2}} \qquad (1)$$

where W = flow in lbs. per hour
C = Coefficient = 0.61 used as a value sufficiently close for most industrial purposes;
A = pipe area in square inches;
S_t = density of fluid at flowing conditions in lbs. per ft.^{3}.
g = acceleration due to gravity = 32.16 ft. per sec. per sec.
h = differential of manometer fluid in inches;
S = density of manometer fluid in lbs. per ft.^{3};
R = the ratio of pipe diameter to orifice diameter = D_1/D_2.

Solving the above formula for R gives the ratio of pipe diameter to orifice diameter sufficiently close for many industrial purposes:

$\therefore D_2 = D_1/R$ orifice diameter where D_1 = pipe diameter.

Should the conditions be right for a good orifice installation and metering accuracy be desired, then formula (1) can again be used by applying proper correction factors.

Suppose you wish to meter a low-pressure gas at a high temperature as high a degree of accuracy as possible, we can then apply correction factors to correct for compressibility, expansion of orifice due to temperature and a more accurate coefficient. The formula then becomes:

$$W = \frac{7.22\,C\,A\,S_t\,Y\,F[2gh(S-S_t)/S_t]^{1/2}}{(R^4-1)^{1/2}} \qquad (2)$$

where C is the correct coefficient. However, the correct value of C and compressibility factor Y depend on the orifice ratio which we do not know.

It is necessary, therefore, to find an approximate orifice ratio; which can readily be done by letting C equal 0.61, Y equal 1 and F equal proper factor as found from curve on page 91 of fourth edition of ASME "Fluid Meters." By the use of this approximate orifice ratio and Reynolds number, C for vena-contracta taps can be found on curve sheets Figs. 69 to 71 inclusive of the above publication. By using this same approximate orifice ratio, Y can be found from curves of Fig. 72 of the same publication.

An orifice designed by formula (2) will be sufficiently accurate for practically all meter installations in industry requiring high accuracy.

"Toward Improving the Utility of ASME-AGA Orifice Coefficients"

[Article by Theodore F. Falls and George B. Bailey in Oct. 1944 *Instruments*, pages 601-602]

DISCUSSION

By R. E. SPRENKLE, Hydraulic Engineer, Bailey Meter Co., Cleveland, Ohio

THE difficulty of designing orifices based on the information given both in the Joint ASME-AGA Orifice Coefficient Committee Report of 1935, and in the ASME Fluid Meters Committee Report Part I, 1937 edition, is quite obvious, as pointed out by the authors of this article.

The present writer desires, however, to call attention to the following procedure as being not only fast, but accurate and practical, and which has been used for a number of years with complete satisfaction.

PREPARATION FOR ORIFICE DESIGN

The authors' equation No. 4 can be rewritten as follows:

$$w' = 358.9\,K\,D_2^2\,(h\rho)^{1/2} \qquad (1)$$

where w' equals the number of pounds of fluid flow per hour. This equation is similar to equation 99, page 49 of the Fluid Meter Report referred to above.

By substituting the value of D_2 shown in the authors' equation No. 3 in the above equation No. 1, we obtain

$$w' = 358.9\,K\,B^2 D_1^2\,(h\rho)^{1/2} \qquad (2)$$

We now combine several factors into one, called Capacity Factor E, or

$$E = 358.9\,K\,B^2 \qquad (3)$$

Substituting in equation No. 2, we now have:

$$w' = E\,D_1^2\,(h\rho)^{1/2} \qquad (4)$$

and rearranging the terms:

$$E = \frac{w'}{D_1^2 (h\rho)^{\frac{1}{2}}} \qquad (5)$$

assuming various values of B, sponding values of E can be com- d for each pipe size (since the co- nt K varies with pipe size) at a tant Reynolds number R_d of 1,000,- These E values can either be plot- on separate curves for each pipe or placed in tabular form, as de- d. Other curves can be prepared ving the correction factors C_{Rd} re- d for deviation of Reynolds num- from 1,000,000. This correction is rporated in equation 5 as follows:

$$E' = E/C_{Rd} \qquad (6)$$

Design Procedure

The procedure for designing any ori- e is then quite simple. First, substi- te in equation 5 the known values of pacity, pressure, temperature, pipe ameter, and meter differential head, d solve for E. From the proper size curve or table determine the corre- sponding approximate diameter ratio B. Since $D_2 = BD_1$, the approximate orifice diameter is obtained, and then the value of the actual Reynolds num- ber R_d. This value is sufficiently close to require no readjustment, even though the final orifice hole may be slightly different from the approximate size.

By substituting the corresponding correction factor C_{Rd} together with the value of E (from Equation 5) in Equa- tion 6, the adjusted value of E' is ob- tained. From this, the final orifice diameter is determined directly from the proper E curve.

As noted, this procedure requires only one readjustment which is simple and direct. Actually, since the variation of the usual Reynolds number from the 1,000,000 standard seldom results in a correction C_{Rd} of more than ½% to 1%, this correction can be disregarded in many cases, resulting in a direct calcu- lation from Equation 5.

Reynolds Number R_d

In answer to the authors' query as to why Reynolds number R_D based on pipe diameter was not chosen instead of R_d, there were at least two reasons for the selection of R_d based on orifice diameter. One of these was the better correlation of the data in the viscous flow region, and another was the fact that R_d had already been used extensively in this country. Actually, it matters little, perhaps, which system is used, for since both R_D and R_d vary with velocity and size of pipe or orifice, the value of K must vary likewise; viz.:

$$K = f(R_d B D) \quad \text{or}$$

$$K = f(R_D B D)$$

Therefore, a readjustment must theoretically be made in the orifice de- sign with the use of *either* R_d or R_D, to compensate for the actual value of K. Actually, however, with the pro- cedure outlined above, this readjust- ment is so small that in many instances it can be eliminated entirely.

AUTHORS' CLOSURE

By THEODORE F. FALLS and GEORGE B. BAILEY

Mr. Sprenkle's comments are appre- ciated, particularly as he describes a method of orifice computation which is typical of what we pointed out to be the present limit of the art. We agree with him completely that this present method can be handled with as much facility as the one we propose—*at high Reynolds Numbers* where there is little or no change in the value of the coeffi- cient.

The E of Mr. Sprenkle's equation No. 5 (E=358.9K) differs from the β^2K factor discussed in the paragraph following our equation No. 4 only by the inclusion of the constants-and-con- versions factor. This is wholly a matter of personal preference. Our own inclin- ation is to use the constants-and-con- versions factor, independent of β^2K, as a vehicle for the various flow-rate units met in practice; but we believe sin- cerely in accepting the established pat- tern in this matter when dealing with the work of a particular staff, since there is so little advantage either way.

The real question at issue is whether Mr. Sprenkle's E (or our β^2K) should be correlated with R_d or with R_D—or, as we emphasized, with the inverse of R_D.

The use of R_D (or its reciprocal) eliminates completely the readjustment of the computation in orifice design in the lower turbulent regions despite the general impression to the contrary. This can be demonstrated rather simply. R_D is independent of orifice diameter by definition. A selection of β from a set of values of β^2K in an R_D argu- ment must be final since none of the computed values of the problem are affected by the selection. Most of us realize that with the use of R_d, the re- adjustment does not represent any change in the basic values in the prob- lem, but rather a change in the com- puted value of Reynolds Number de- pendent upon the value of β. The read- justment is simply a step-by-step ap- proximation method of correcting a false premise toward reality.

What has not been understood, pre- viously, is that the manifold of K vs. β and R_D is just as rigid and consistent a system as K vs. β and R_d. We have never found any discussion of this point in the literature, nor are we prepared to support it with any rigorous proof. On the other hand the soundness of the step is justified within the structure of the empirical equations of Buckingham, insofar as these have been published, and in consideration of the relation of R_d and R_D by definition.

The linearity of K vs. $1/R_D$ for any given β we think to be a matter of prime importance. Not only does such a relation indicate a possible physical law, but it markedly condenses and facilitates the use of the tables of coeffi- cients and the dependent β^2K. This is important in selecting orifices, and it is of particular service in designing compensation for Reynolds Number variation in flowmeters working in the lower turbulent ranges.

Mention of the linearity of the coeffi- cient with $1/R_d$ appears in the descrip- tion of the analyses of the experimental data in the publications of the Joint Committee. Mr. Howard S. Bean clearly shows this condition in at least two of his articles: *American Gas Association Monthly*, July 1935, pages 259 et seq., and *Pennsylvania State College Mining Industries Experimental Station Bulle- tin* No. 20 (1936), pages 74 et seq. We regret that we were not aware of this work until some time after our paper went to press, for we would have pre- ferred to acknowledge it in our original paper. The persistence of this linearity in terms of $1/R_D$ is most surprising, but it also is justified within the struc- ture of Buckingham's empirical equa- tions. The decision to array the coeffi- cients against R_d in preference to the reciprocal as advocated by Mr. Bean was unquestionably made in good faith in the light of current theory; but it obscured a step of considerable eco- nomic value to the industry.

"Designing an Orifice"—Sheep in Lion's Clothes

(AN EDITORIAL)

The expression "designing" an ori- fice suggests highbrow work: the *design* of the orifice shape, thickness, size and angle of bevel, etc. Actually, all the user has to do is to *determine the diameter* and to order an orifice plate of that size. A few multiplica- tions and divisions *may be* required, and looking up tables, but no "math- ematics."—M. F. Behar

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ol. IV, No. 3 M. F. Béhar, Editor March 1945

Automatic Electric Control of Engine Temperature by Cooling-flap Positioning

By RUSSELL A. GUND, Industrial Control Engineering Div., General Electric Co., Schenectady, N. Y.

AUTOMATIC CONTROLLERS have become increasingly important as more complex, higher-speed airplanes have been designed. These automatic devices are especially important in military aircraft because the less attention the pilot and crew must give to the functional details of the airplane, the more attention they can give to fighting, bombing, photographing or other military missions.

One of the airplane mechanical functions which has recently been automatized is the operation of cooling flaps. All high-performance airplanes are equipped with operable cooling flaps. These flaps cool the engine head, oil, or carburetor air—whichever the case may be. For maximum aircraft performance, these flaps should never project farther into the airstream than necessary. When the flaps are controlled manually, the pilot or flight engineer must continually follow his temperature-indicating instruments and constantly make corrections in flap position if the best performance is to be obtained from the airplane. With the automatic temperature control system described below, this is done without any attention from the flight personnel.

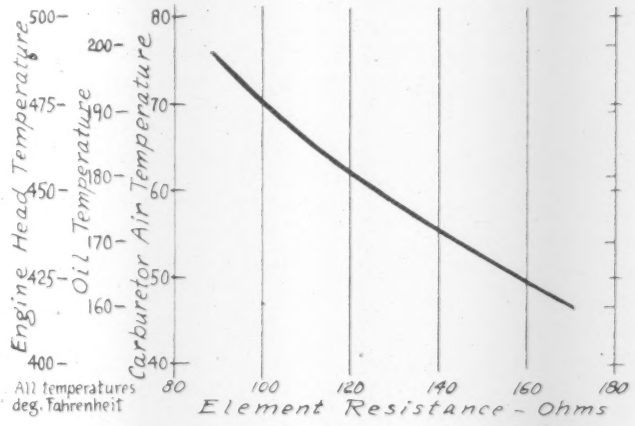

Fig. 1. Temperature-resistance curves for engine-head, oil and carburetor-air temperature-measuring elements.

Since the flap position depends upon the temperature, it is apparent that the flaps are at the minimum required opening at all times, and thus produce a minimum drag. Engine life is also lengthened, because the temperature tends to stabilize as low as is possible for the engine power maintained.

The devices necessary for automatic temperature-control of airplane engines through cooling-flap position control are as follows:

1. A cockpit switch for selecting manual or automatic operation.
2. A temperature-measuring element.
3. The "controller" proper: the "brain" which commands the flap actuator.
4. The actuator which opens and closes the cooling flaps.
5. A follow-up unit from which flap position is transmitted to the controller proper.

(Units 4 and 5 are frequently combined to conserve weight and space.)

CLASSIFICATION AND COMPONENTS

This automatic-control system belongs to the electrical class, as distinguished from the pneumatic, hydraulic and composite categories (but it may comprise a hydraulic actuator as its final element). Its action is not on-and-off but what we call "band-modulating temperature control." Band modulating temperature control may be defined as that type of action which recalibrates the temperature-measuring element as the flaps assume successive positions. The control starts to open the flaps at some predetermined temperature, then, at the highest allowable operating temperature, the flaps will be full open. The controller can stop the flaps at any position between "OPEN" and "CLOSED," the position depending upon the temperature.

PRINCIPLES OF OPERATION

We may consider the temperature-measuring element to be a dial thermometer and the controller proper to be the flight engineer. The flight engineer watches the thermometer. If the engine temperature starts rising above a point which he considers proper for the power output of the engine, he will move the flaps toward "OPEN" until the engine reaches temperature equilibrium. Also, if the engine is running too cool, he will run the flaps in the "CLOSED" direction to raise the temperature. In other words, the flight engineer operates the flaps between full "CLOSED" and full "OPEN" to try to keep the engine temperature within a maximum and a minimum temperature. The automatic controller does the same thing: When the temperature rises above the minimum temperature, the primary-element's signal starts unbalancing the controller. After a certain amount of unbalance, the controller commands the actuator to start opening the flaps. While the flaps are opening, a rheostat in the follow-up unit rebalances the controller and the flaps stop in a new position. If temperature equilibrium is not obtained, the same procedure is fol-

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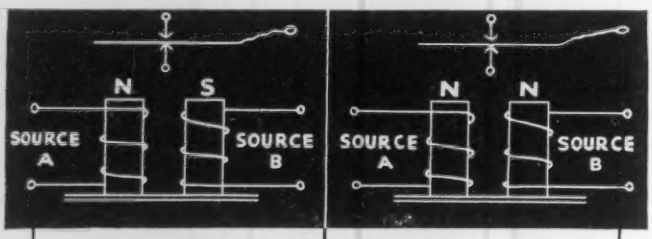

CASE 1 | CASE 2

Energized from separate sources, coils may be connected to produce aiding or opposing forces according to functional requirements.

IN CASE 1, above, sources A & B may be *insufficient* power to operate the relay separately, but simultaneous currents cause the relay to operate.

IN CASE 2 equal inputs from sources A & B create opposing forces which balance and prevent operation. However, a differential current of only a few milliwatts will cause positive relay action. Each coil may be drawing power up to many times that required to operate the relay without seriously affecting its sensitivity to the differential current. Sigma Series 5 relays are regularly furnished with two coil terminals on a 5-pin base. When three or four coil terminals are needed this arrangement can be furnished in the F type without cover or base or in the R type with rectangular cover and molded base carrying terminal lugs and mounting ears. This permits mounting above deck and wiring below deck.

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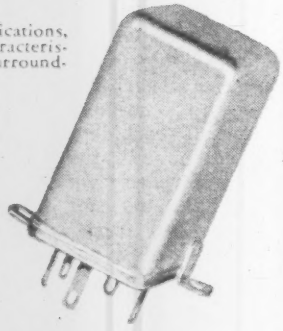

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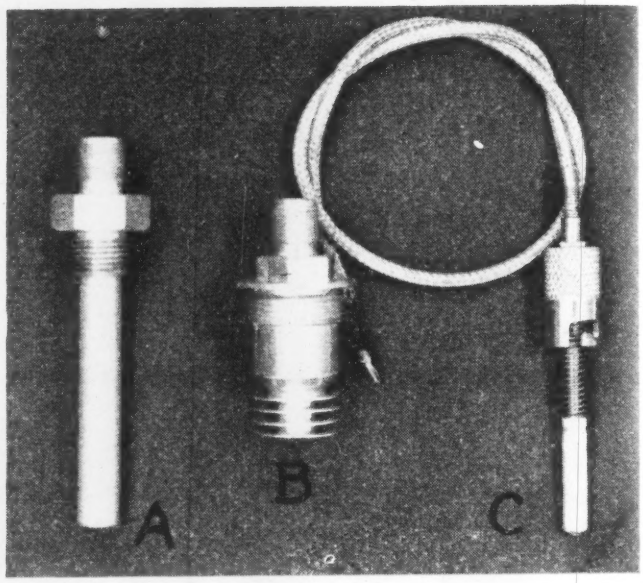

Fig. 2. Primary elements for: (A) oil, (B) carburetor-air and (C) engine-head service.

lowed until it is. The flaps will either open or close to follow increasing or decreasing temperature.

DESCRIPTIONS AND FUNCTIONS OF COMPONENTS

The cockpit switch has an "OFF" position and an "AUTOMATIC" position; both positions are of the maintaining-contact type. It also has two "MANUAL OVERRIDE" positions to manually open and close the flaps for ground running or emergency conditions. These are momentary contacts.

The primary temperature-measuring element is made of a material having a high negative temperature coefficient of resistivity, that is: (1) the resistance of the element varies inversely as the temperature and (2) the material's characteristic curve is such that small changes in temperature are converted into large changes in resistance. The "rate" or "response" of the elements is as high as that of the commonly-used thermocouple, or higher. Fig 1 shows the relatively high percent change in resistance for a relatively low change in temperature (within each type's temperature span), evident in the temperature-versus-resistance curves of the engine-head, oil and carburetor-air elements.

Fig. 2 shows the three types of units. (Left to right: oil, air and engine-head.)

The oil unit is screwed into a fitting in the oil line. It is

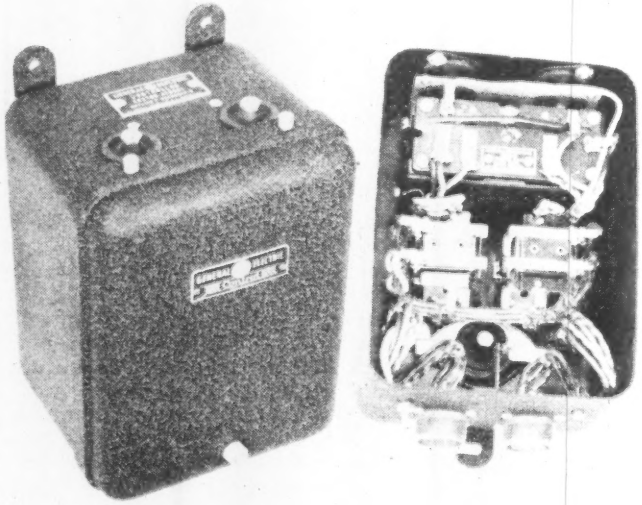

Fig. 3. Two views of enclosed-type temperature controller.

58 OPERATIONS

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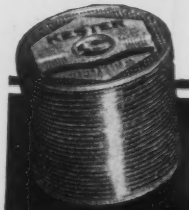

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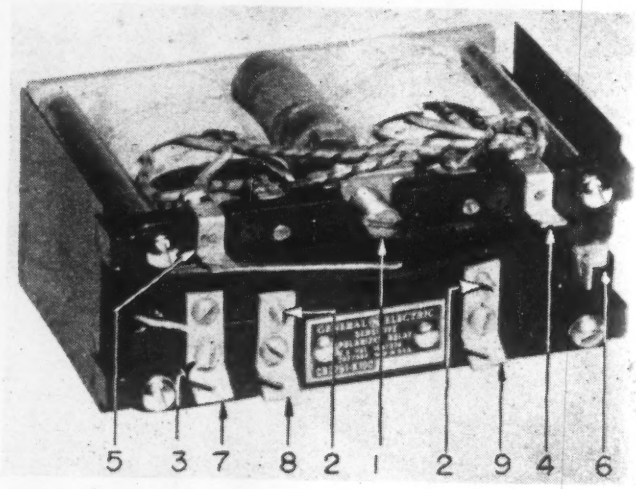


Fig. 4. Polarized relay.

grounded electrically in the fitting and makes thermal contact with the oil flowing by.

The carburetor air unit is screwed into the duct between the intercooler and the carburetor, and makes electrical and thermal contacts in the same manner as the oil unit.

The engine-head unit is inserted in a well drilled into the cylinder head of the engine. It makes thermal contact and is grounded electrically through the end point.

The controller proper, Fig. 3, consists of an extremely sensitive polarized relay and power relays. The power relays are used to start and stop the motor in either direction. They are of conventional design and need not be discussed here. The polarized relay works in conjunction with the temperature-measuring element and the follow-up rheostat and controls the power relays.

The polarized relay, Fig. 4, consists of a permanent magnet, two coils, and a balanced armature. Each coil has an inside and an outside winding; both inside windings are connected in series and to terminals 4 and 5, while both outside windings are connected in series and also to terminals 4 and 6. The inside windings have twice as many turns as the outside windings, but both windings have equal resistance. The armature has a common connection at terminal 7 which may contact either terminal 8 or 9.

Fig. 5 shows an elementary diagram of the complete cir-

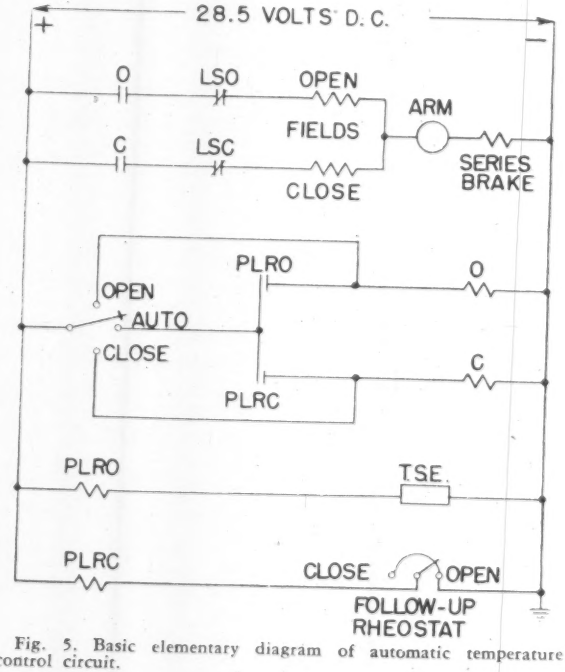
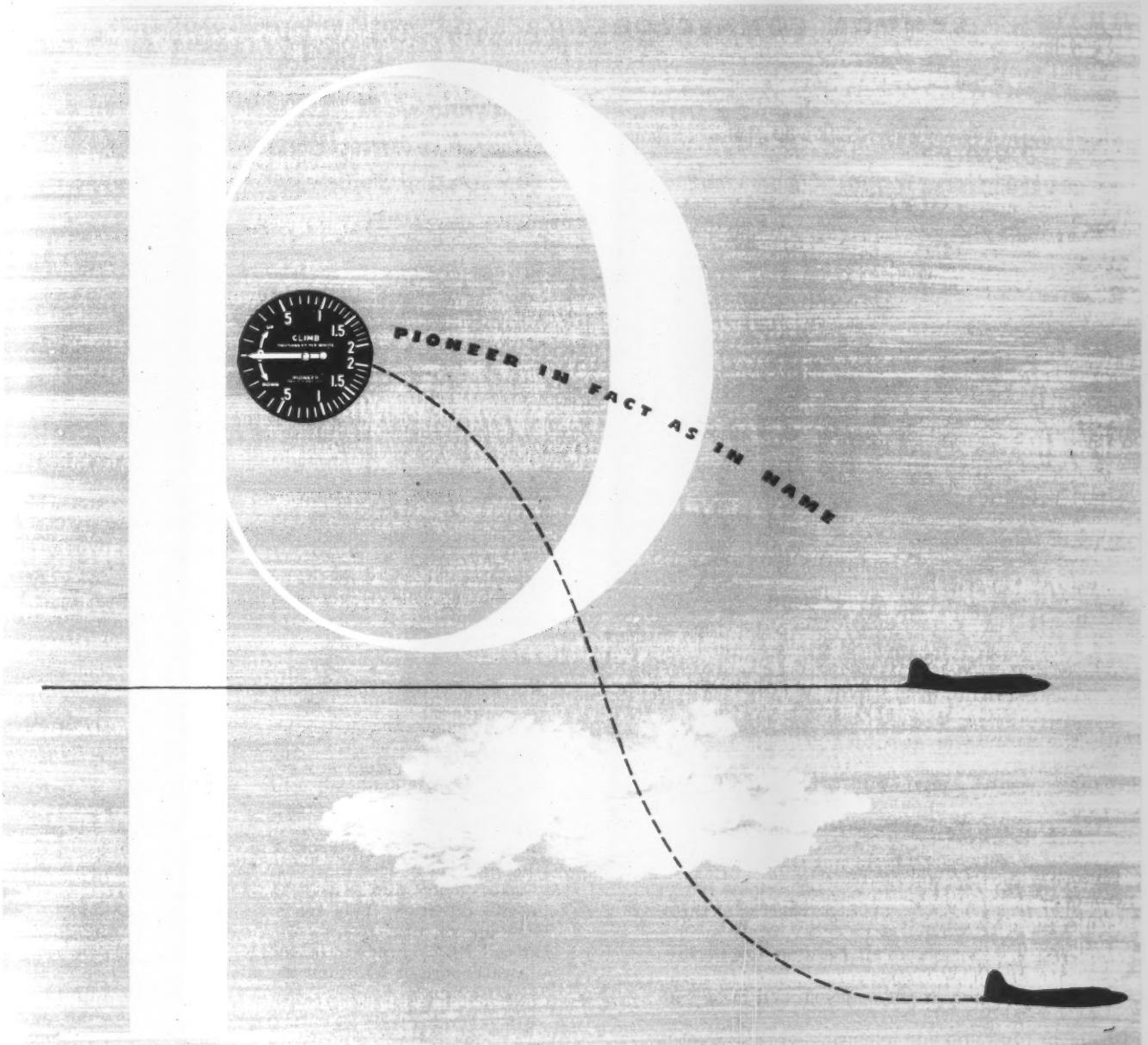


Fig. 5. Basic elementary diagram of automatic temperature control circuit.



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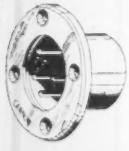

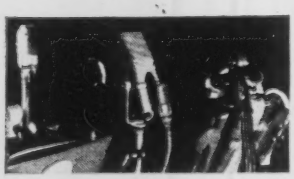

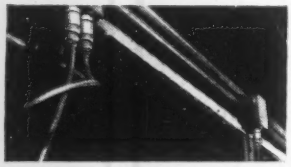

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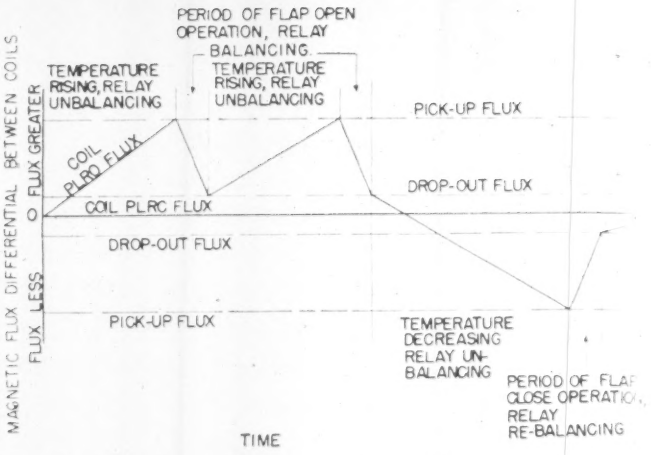


Fig. 6. A graphic illustration of the polarized relay operating principle.

cuit. The inside windings are coil *PLRO* and the outside windings are *PLRC*.

Referring to the above description of the relays, coil *PLRO* has twice as many turns as coil *PLRC*. Therefore, to balance the relay, the current through coil *PLRC* must be twice as great as the current through coil *PLRO*. In other words, equal ampere-turns produces equal flux. Because this condition must be met to balance the relay, the temperature-measuring element must have a resistance equal to the resistance of coil *PLRC* plus twice the resistance of the follow-up rheostat.

Inasmuch as the temperature-measuring element controls the flap position, the excitation of coil *PLRO* is always changed first and the relay returned to balance by correcting the excitation of coil *PLRC* with the follow-up rheostat. Fig 6 is a graphic presentation of the change in flux differential between coils *PLRO* and *PLRC*. Fig. 6 is purely hypothetical and, is only used to illustrate the relay operating principle. Note that once the relay starts operating, it takes more differential to pick up the relay in the opposite direction. This tends to stop hunting due to the follow-up rheostat overshooting. It is interesting to note that coil *PLRO* needs to be energized only eight-tenths of a milliwatt more or less than its balancing excitation to operate the relay.

Figs. 7 and 8 are typical examples of follow-up units. Fig. 7 shows the follow-up unit mounted on the actuator, while Fig. 8 shows a follow-up transmitter which is operated directly from the flaps. Both of these units incorporate a rheostat and limit switches. The rheostat controls the width of the temperature band in the manner previously described.

The follow-up rheostats should have a tapering effect, since a given flap change near the flap CLOSED position produces more cooling effect than the same amount of flap change near the flap OPEN position.

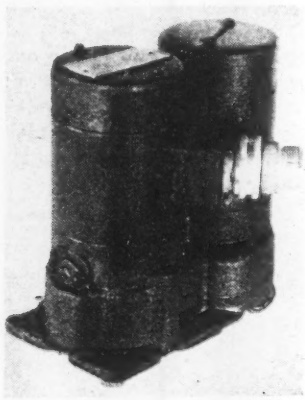
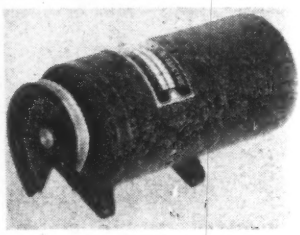


Fig. 7. Gear-motor complete with follow-up motor.

Fig. 8. Follow-up transmitter.



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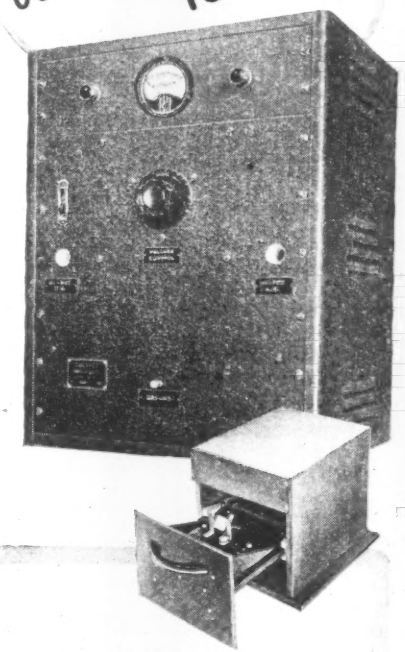

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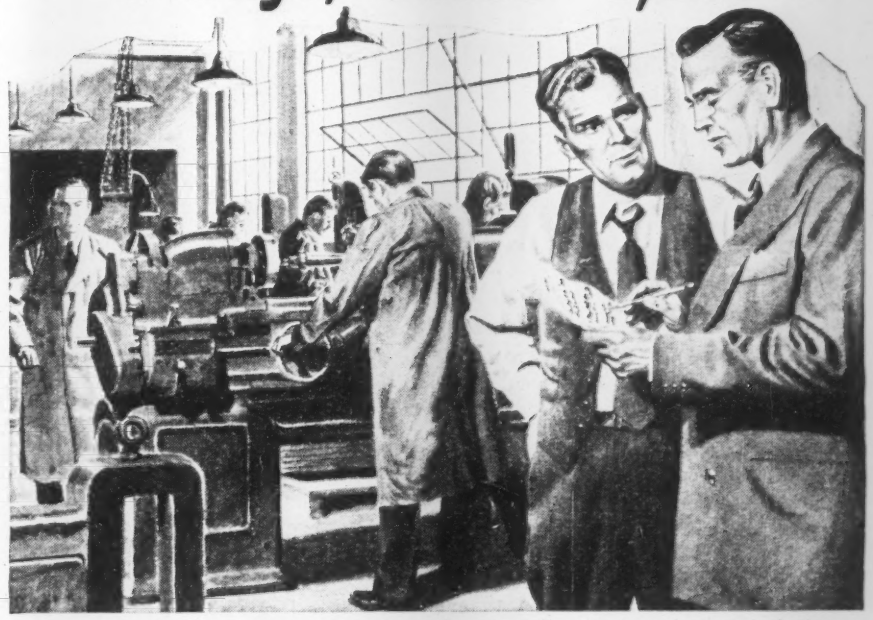

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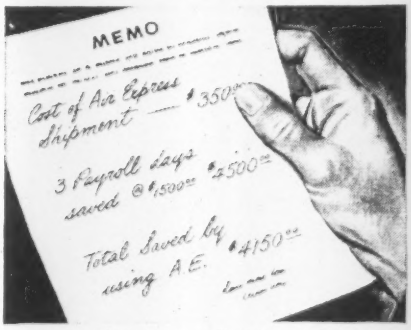

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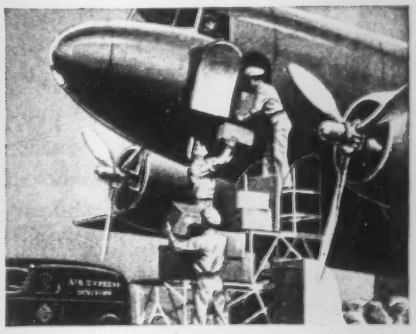

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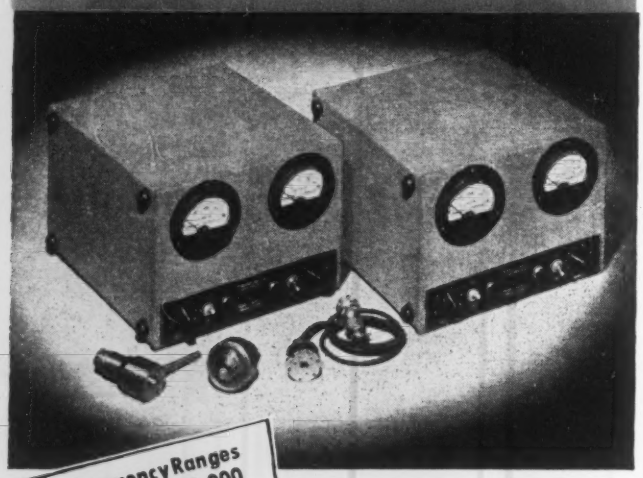

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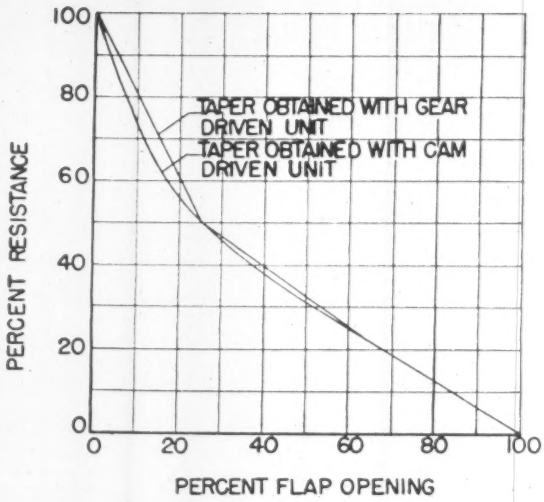

Fig. 9. Typical percent resistance vs. percent flap opening curves for gear driven and cam operated follow-up units.

The rheostat in the follow-up unit, which is incorporated with the actuator, has a tapered winding. The separately-mounted follow-up unit produces the taper by the cam action. Fig. 9 shows the ideal taper obtained from the cam and the compromise taper obtained by a tapered rheostat winding.

Any conventional actuator can be used with this system so long as it can be stopped quickly. The system lends itself to either the motor-operated actuator or hydraulic-operated actuator.

SYSTEM OPERATION

Referring again to Fig. 5, when the medium to be cooled is at a low temperature, the flaps are closed. The follow-up rheostat then has full resistance in coil *PLRC* circuit. As the medium rises in temperature, the temperature-measuring element (*T.S.E.*) decreases in resistance until the excitation of coil *PLRO* is greater than that of coil *PLRC*. This causes contact *PLRO* to close, exciting coil *O*. When coil *O* is energized, it closes contact *O* which energizes the

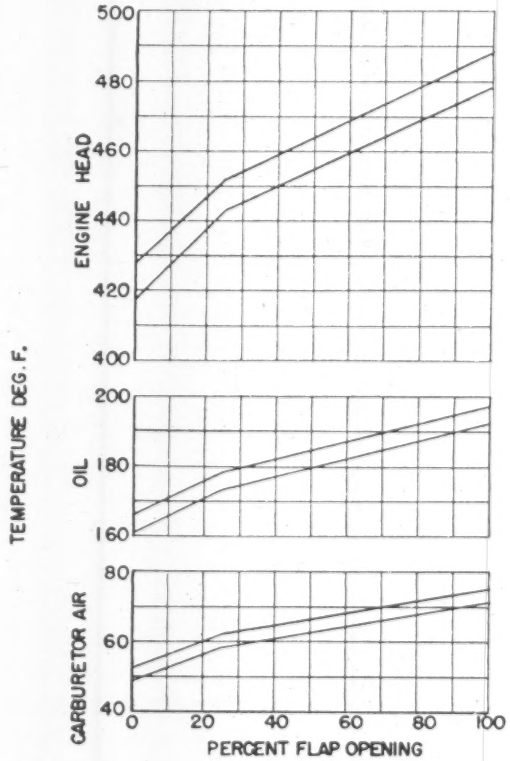

Fig. 10. Calculated envelopes of temperature vs. percent flap opening for engine head, oil, and carburetor air service.

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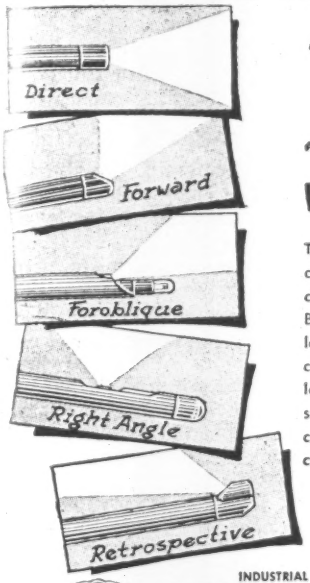

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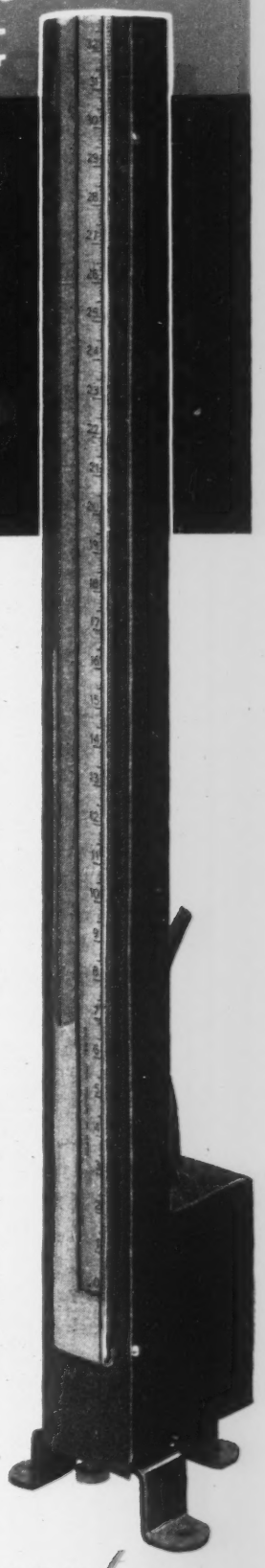

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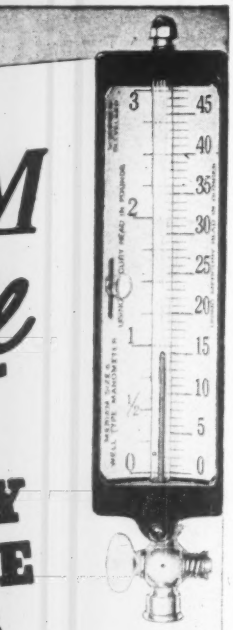

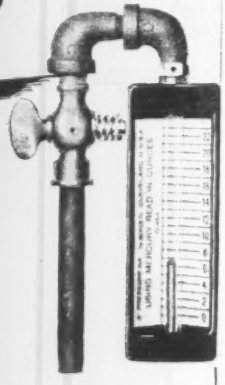

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motor in the open direction. As the flaps are opened, the follow-up rheostat decreases in resistance until coil *PLRO* is energized the same amount as coil *PLRO*. This causes contact *PLRO* to open, deenergizing coil *O*, and opening contact *O*. This deënergizes the motor and sets the series brake, thus stopping the flaps at an OPEN position. If the medium to be cooled is not yet receiving enough cooling air the same procedure is followed. The flaps will stabilize at some point wherever the cooling air is equal to the heat release of the medium.

If the medium drops in temperature, then the temperature-measuring element increases in resistance until coil *PLRO* is energized less than coil *PLRC*. This causes contact *PLRC* to close, energizing coil *C* and causing contact *C* to close, which energizes the motor in the CLOSE direction. As the flaps are closed, the follow-up rheostat increases in resistance until the excitation of coil *PLRC* is reduced to equal that of coil *PLRO*. When the coils are balanced, contact *PLRC* opens, deenergizing coil *C* and opening contact *C*. This deënergizes the motor and sets the series brake to stop the flaps at a further closed position. Limit switches *LSO* and *LSC* limit the flap travel in the OPEN and CLOSE directions.

Fig. 10 shows the various envelopes of temperature versus-flap-opening for the engine head, oil, and carburetor air service. These curves are plotted assuming a 32-ohm follow-up rheostat following the typical taper curve of Fig. 9 and using primary element characteristic as shown in Fig. 1.

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ELECTRIC GAGING METHODS

Continued from Page 151

In a device for measuring fluid pressure, two crystal elements are placed in contact with a thin metallic electrode between them, and this assembly is placed within a metallic sleeve containing a diaphragm which receives the fluid pressure and transmits it to the crystal assembly. Such an assembly is shown in Fig. 118B. This method of construction combines several advantageous features. Protection from the chemical effects of the fluid is afforded as well as some isolation from high gas temperatures when the unit is used as an engine-indicator element. An initial polarizing force is applied to the crystals; thus the unit can respond to low pressures. Since force is applied to the crystal elements at all times, rapidly changing pres-

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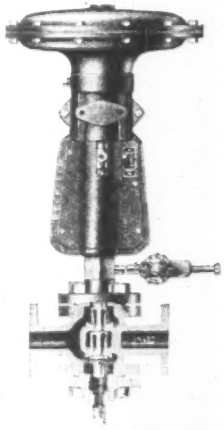

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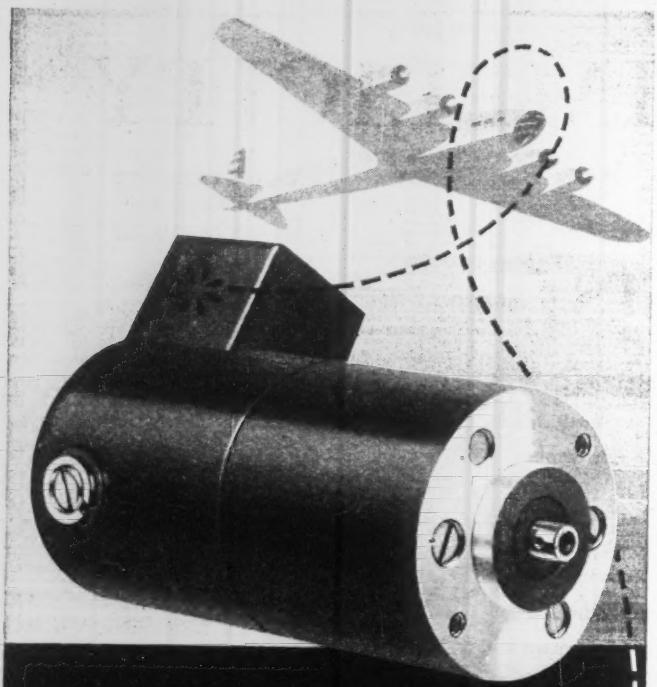

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sures do not produce "chatter" of the crystal slices with consequential electrical disturbance in the output. And since the central ungrounded electrode is insulated by the quartz crystals themselves, the d-c. resistance may be kept high and the leakage low. It is not practicable to make the natural frequency of the entire unit as high as that of the crystals

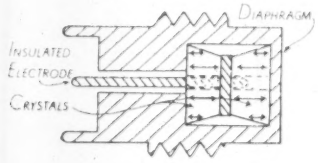

FIG 118B

but it is not difficult to achieve satisfactory results for frequencies as high as 10,000 cycles per second. The low-frequency response is limited by the leakage of the pick-up and the characteristics of the amplifier used; special designs in resistance-coupled amplifiers provide good response down to as low as one cycle in four or five seconds. This range is as wide as is needed for motor combustion studies.[262, 263] Quartz crystals in this application can safely withstand mechanical loads as high as 40,000 lbs./in.^{2}, although best operation is obtained if this working limit is not approached. With crystal elements having areas of about one-fifth square inch, the total force which can be accommodated is about 8,000 lbs., but it is desirable to apply no more than some 2,000 lbs. For measurement of low pressures, a "mechanical amplifier" can be incorporated into the device: a diaphragm having a greater area can be installed.

Any unit so constructed, however, inevitably is subject to errors caused by vibration: the forces caused by accelerations acting directly on the crystals will produce electric charges in the same manner as the forces which are deliberately introduced. The construction shown in Fig. 118B minimizes this danger, since two crystal elements are used, so arranged that acceleration forces applied equally to both will tend to produce charges on the electrodes in opposite polarities and therefore balancing each other. A much better method is the installation of two similar crystal assemblies, one subjected to the diaphragm pressure, and both equally subjected to vibration.[264] The outputs of the two can be combined to balance out the acceleration potentials, or can be recorded separately. Or such spurious responses can be reduced by placing the crystal elements in carefully damped mounts.[265]

Quartz, however, while mechanically strong, and resistant to heat and other disturbing factors, is relatively insensitive. In order to increase this sensitivity, some pick-ups employ a number of crystal elements arranged both mechanically and electrically in series. Since the potential produced by a piezoelectric crystal is directly proportional to the force—not the pressure per square inch, but the total force—applied to that crystal, an obvious method of increasing the potential output is through the use of several crystals. If they are connected in series electrically, their output potentials will be additive, while if they are arranged in series mechanically (in a stack or pile) the same forces will act on all elements alike. By this means the voltage output of the device can be increased from the usual value of about 0.0003 volt per pound for the single-crystal unit to a value several times as high.[266] This increase in potential output, however, is obtained at the expense of increasing the impedance of the unit by several hundred percent from an already-too-high value.

The mode of assembly for such a pick-up is indicated in

(262) S. Kluge and H. J. Linckh. Piezoelektrischer Indikator fuer schnellaufende Verbrennungsmotoren. *Zeitschrift des Vereins Deutsches Ingenieure*, Vol. 74, 1930, pages 887-889.

(263) H. J. Schrader. Cathode-ray Engine-pressure Measuring Equipment. *RCA Review*, Vol. 2, 1937, pages 202-212.

(264) F. Postlethwaite. Measurement of Detonation. *Aircraft Engineering*, Vol. 10, 1938, pages 201-205, 211.

(265) W. Gohlke. Piezoelectric Pressure Recorders of High Natural Frequency. (Translation) *Journal of the Royal Aeronautical Society*, Vol. 47, October 1943, pages 555-557.

(266) Anonymous. Internal Combustion Engine Analysis. *Electronic Industries*, Vol. 2, June 1943, pages 64-65.

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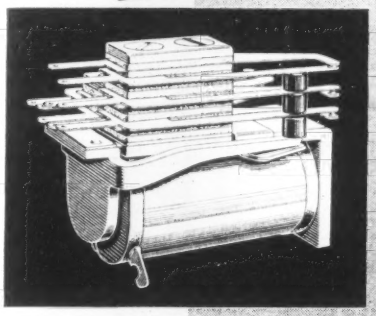

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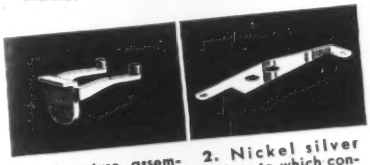

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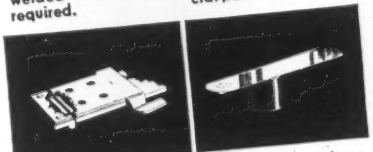

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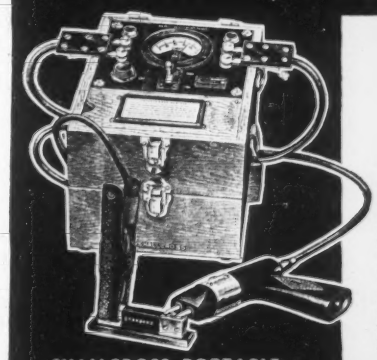

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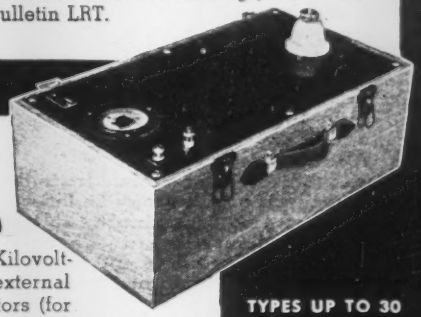

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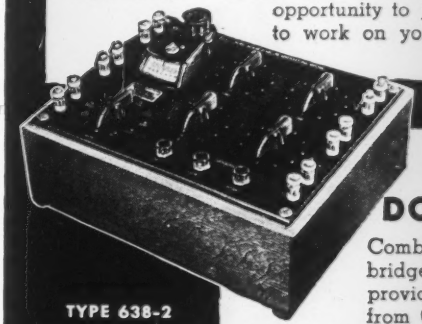

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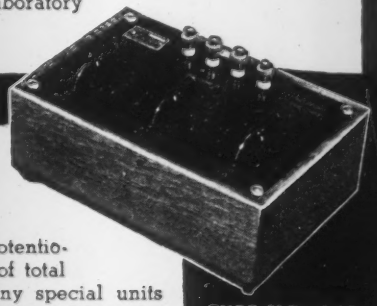

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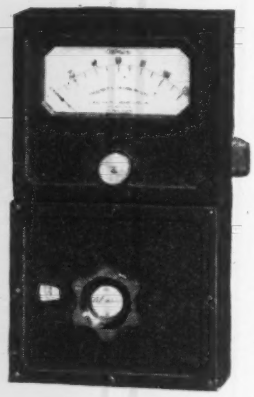

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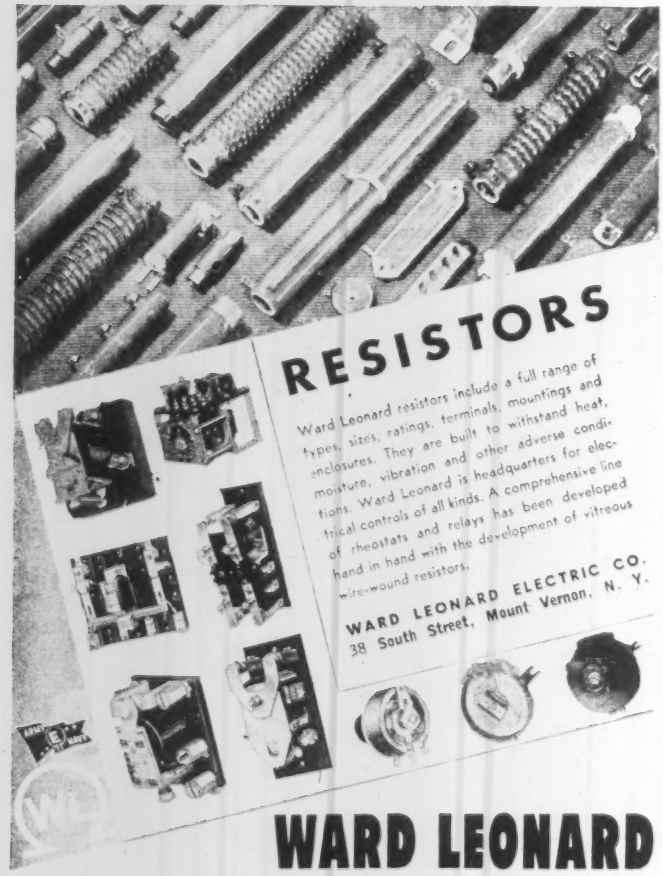
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Fig. 119. The individual crystal elements are usually cut quite thin, thus lowering the impedance of the unit. The mechanical strength of such a device is rather high, but because of the danger of breaking crystal elements, loads higher than perhaps 2,000 pounds (for the average pick-up having a crystal area of about 1/5 square inch) should be avoided. Such thin crystals, unless perfectly seated, are easily broken.

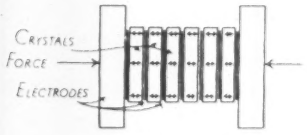

Fig. 119

Multi-element crystal pick-ups have been satisfactorily employed in the measurement of breech pressures in large-bore artillery, and in recording low-frequency accelerations.[267, 268] In both applications, extreme low-frequency response is desirable, and direct-coupled amplifiers are often used. High gain is not easily obtained in such amplifiers, so that the higher voltage output of the multi-crystal element is advantageous.

The quartz piezoelectric crystal in the simple mechanical arrangement of Fig. 116A and Fig. 118 has been applied to a remarkable variety of measurements. In measurements of the tensile strength of thin fibers, loads (applied by electric solenoids) were measured by means of piezoelectric elements and electrometer circuits.[269] The steam pressure in locomotive cylinders, the sideward forces acting on the rails, and the various motions and forces acting in high-speed railway equipment have been recorded by such pick-up devices.[270] Vibrations caused by traffic,[271] by heavy machinery and impact shocks as severe as 5,000 times normal gravity have been measured by portable piezoelectric measuring instruments.[272]

It has been the practice to employ quartz crystals for mechanical measurements where either high rates of acceleration or large forces were present, since the much lower mechanical strength of the next most common material, Rochelle salt, discourages its application under such circumstances. But its much higher sensitivity (more than a thousand times that of quartz) makes it uniquely fitted to certain uses.

The use of the Rochelle-salt crystal pick-up in the Brush Surface Analyzer, for surveying a machined surface and recording its contours greatly magnified, is so well-known as to require no detailed description. This instrument employs a bimorph crystal as the primary element, and another as the pen-drive in an ink-writing oscillograph.

Rochelle-salt piezoelectric elements—usually of the "bender" type, upon which sound waves impinge directly—have sufficient sensitivity to be used as acoustic measuring devices with portable amplifiers. Vibration pick-ups, incorporating "twister" elements inertia-coupled to the surface or machine under test, are in common use.[259] These instruments can measure vibration amplitudes as low as 0.001", frequencies as low as 10 cycles per second, and may be fitted with integrating or differentiating circuits.

The high intrinsic sensitivity of the Rochelle salt crystal element makes its use desirable in some biological and physiological applications. Piezoelectric stethophones are of great value in electrocardiography and in medical in-

(267) R. H. Kent and A. H. Hodge. Use of the Piezoelectric Gage in the Measurement of Powder Pressure. *Transactions, American Society of Mechanical Engineers*, Vol. 16, 1939, pages 197-20[illegible]

(268) P. Hackmann. Ein Beschleunigungsmesser nach dem piezoelektrischen Verfahren. *Jahrbuch der Deutscher Luftfahrtforschung*, 1938, part I, pages 628-630.

(269) F. Seidl. Piezoelektrische Bestimmung der Zugfestigkeit von duennen Metall-, Glas-, und Quarzfaeden. *Zeitschrift fuer Physik*, Vol. 75, 1932, pages 735, 740.

(270) M. Mauzin. Applications des méthodes piézo-électriques à la mécanique industrielle: Mesure des déplacements, des efforts, des accélérations. *Mécanique*, Vol. 23, January-February 1939, pages 13-27.

(271) I. Risch. Messungen von Verkehrschuetterungen. *Verkehrsteknik*, Vol. 46, No. 40, 1929, pages 707-710.

(272) R. O. Fehr. Quartz-Crystal Accelerometer. *General Electric Review*, Vol. 45, 1942, pages 269-272.

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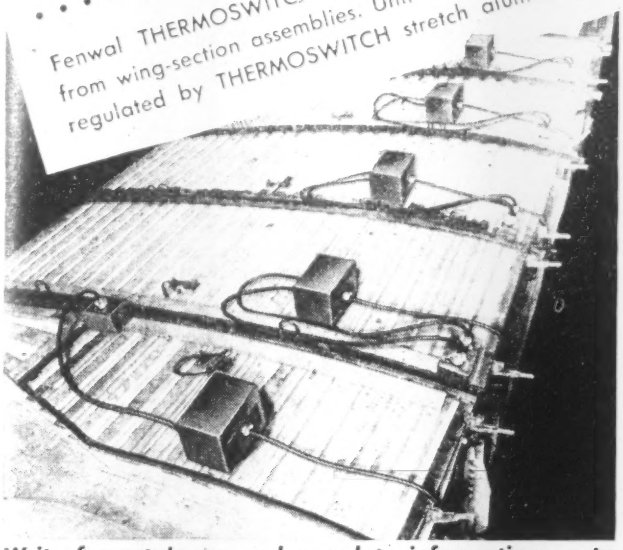

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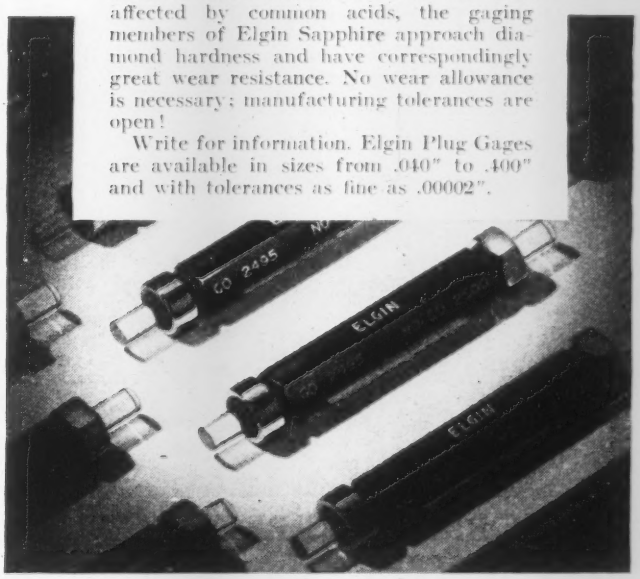

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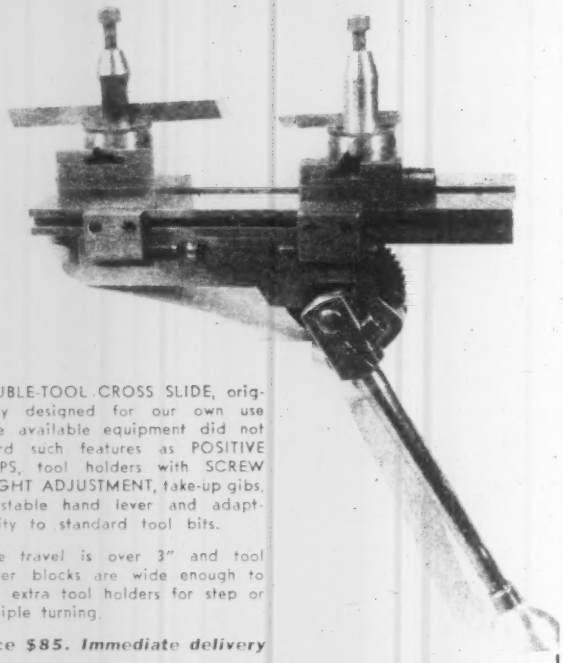

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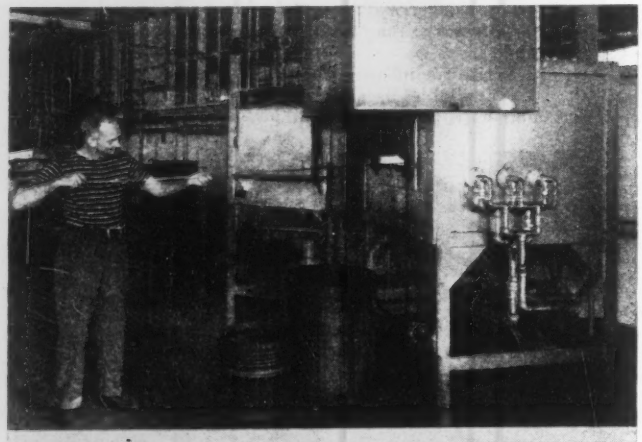

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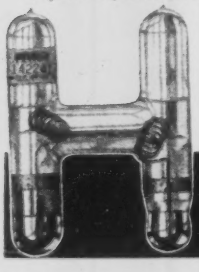

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struction. For military (and other) surgery, piezoelectri elements may be attached to probes and scalpels, increasin the delicacy of the surgeons' touch by many times.[273] Loca tion of foreign bodies is greatly facilitated by such a devic and it is even possible to detect changes in texture of fles being cut by the surgeon. Sensitive pick-ups employin crystal elements have also been employed in recordin pulse-beats and the turbulent flow of blood and othe fluids.[274]

Rochelle salt crystals, although not crystallographical suitable for direct exposure to hydrostatic pressure, hav been employed in sensitive differential-pressure flow-mete ing devices.[275]

In the last few years the application of the piezoelectri crystal as a driving or motor element for oscillographic us has become well established. Because of its high outpu and low cost, the Rochelle salt crystal has been almost ex clusively used in these devices. Composite crystal elements either "twister" or "bender" bimorph elements[259, 276] or th more recently announced "Monobar" crystal are used. Mult plying levers amplify the relatively small motion of the crystal to as much as 1½" amplitude, and operation is satisfactory up to 125 cycles per second.

In another type of testing, the reversible characteristic of the piezoelectric crystal makes possible a most powerful method for measuring distances within solids or liquids by means of ultrasonic radiation. The method is not a new one, but the constantly-growing needs of industry have caused it to be revived and expanded. The first applications of the principle were in subaqueous signalling and surveying;[277, 278] one of the first practical devices for such use was the Langevin-Florisson transmitter-receiver. This device employed a mosaic of quartz crystals sandwiched between two steel plates; it was capable of handling a considerable amount of acoustic energy at a frequency of 38,000 cycles per second. The same device was employed as a transmitter and a receiver for the reflected wave; in use a pulse or short heavily-damped wave-train was sent out, and the distance to the sea-bottom was measured by measuring the time required for the reflected wave to return.*

This principle, on a greatly reduced mechanical scale, has been applied to the detection of voids and cleavages in plate and sheet material,[279] to the measurement of thickness of plates,[280] and to the detection of faults, cracks, and fractures.[281, 282, 283] Three general methods of attack are

(273) V. A. Ostroumov and V. N. Lepeshinskaya. Piezoelectric Surgical Probe. *Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS*, Vol. 38, 1943, pages 82-84.

(274) R. W. Tibbetts. Rochelle Salt Crystal Devices of Low Impedance. *Electronics*, Vol. 16, April 1943, pages 88-90, 116, 118.

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(276) F. Offner and R. W. Girard. A High-speed Crystal Inkwriter. *Science*, Vol. 84, 1936, pages 209-210.

(277) J. J. Thomson. Piezoelectricity and Its Applications. *Engineering* (London), Vol. 107, 1919, pages 543-544.

(278) Ludwig Bergmann. Ultrasonics. John Wiley and Sons, New York, 1939, 264 pages.

(279) A. Trost. Nachweis von Werkstofftrennungen im Blechen mit Ultraschall. *Zeitschrift des Verein Deutsches Ingenieure*, Vol 87, 1943, pages 352-354.

(280) W. S. Erwin. Supersonic Measurement of Metal Thickness. *Iron Age*, Nov. 9, 1944, pages 59-61.

(281) F. A. Firestone. The Supersonic Reflectoscope: An Instrument for Inspecting the Interior of Metal Parts by Means of Sound Waves. *Proceedings of National Electronics Conference*, 1944. (Now in press.)

(282) C. M. Cosman. Ultrasonics—New Testing Tool. *Iron Age*, May 15, 1941, pages 48-50.

(283) Anon. Sheet Fractures Detected with Supersonics. *Iron Age*, June 8, 1944, pages 60-61.

*EDITOR'S NOTE.—Mr. Roberts is justified in including details of echo-ranging methods although most engineers consider echo ranging too inaccurate to come under the head of "gaging." Accurate echo-ranging measurements are already being obtained in geophysical prospecting. Ultrasonic echo-ranging provides bats with a substitute for sight in total darkness, enabling them in laboratory tests to fly through mazes of thin wires requiring a number of distances to be measured almost simultaneously. Ultrasonic echo-ranging methods are theoretically capable of extreme accuracy and they have a promising future because they are non-destructive. The attainment of high accuracy will require appropriate instruments. The essential features of such instruments are military secrets (being utilized in Radar and "Mickey") but will probably be easily adaptable to gaging when made public.—MFB

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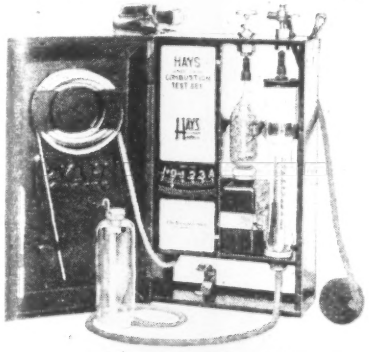

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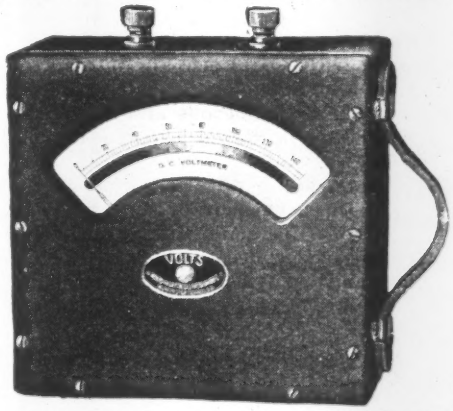

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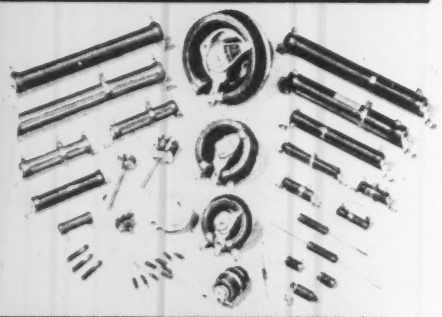

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in use: one is the placement of a sound source on one si of the specimen and a sound detector on the other: if cleavage or void larger than the wave-length of the sou is present, it will screen the detector—cast a "shadow so to speak. This is illustrated in Fig. 120. The seco

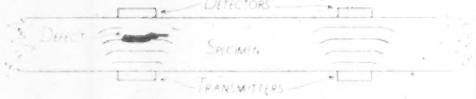

Fig. 120

method is through the use of reflected instead of transmitted sound: a pulse (or a short train of sinusoidal vibrations) is introduced into the specimen, and the reflec pulse observed. Both the time required, and the wave-fo of the reflected pulse, may be used as criteria. This g eral method is illustrated in Fig. 121. The third meth

Fig. 121

employs resonant vibrations: a continuously-variable osc lator is mechanically coupled to the specimen through crystal driving element. The frequency is varied unt resonance occurs (indicated by a change in the rate o energy transfer) at which time the thickness of the meta is known to be an integral multiple of the wave-length in use. In Fig. 122 one possible arrangement is indicated; the wave-pattern drawn there represents that occurring when the plate thickness equals one-half the wave-length.

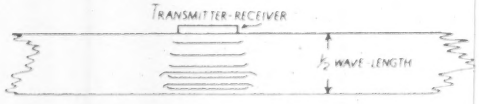

Fig. 122

In any of these methods, experimental difficulty may be expected. The frequencies used must be high (100 kilocycles to several megacycles, depending upon the applica tion) since the wave-length must always be smaller than the least dimension of the flaw being sought for, or smaller than twice the plate thickness. Some means must be employed to insure good acoustic transfer of the sonic energy to the specimen; either a layer of oil or a flowing film of water is ordinarily used. Since any interface between two media of different sound-velocities will produce a reflection, spurious responses are numerous and annoying. Yet, properly applied, the principle is capable of most excellent results.

Other miscellaneous applications for piezoelectric elements include the measurement of time, frequency, etc., and the application of supersonic energy to flocculation and deflocculation of suspended materials. There are many other chemical and biological applications, but they cannot be described as gaging or measuring methods, and will not be discussed.

§ 3. Electric Circuits.

The piezoelectric primary element, like some of those previously described, is a generator of electric potential, and as such is always used with an amplifying system.

The potential output of a quartz crystal is of the order of 0.03 volt per thousand pounds of force applied; this value does not depend upon the area of the crystal element—as a matter of fact quartz crystals can often be used with satisfactory results in measuring devices even after they have been broken into two or more pieces. The potential output of a crystal of Rochelle salt is about a thousand times as great; that is, an output of 0.03 volt can be produced with only a pound or so of force. Obviously the amplification required for quartz-crystal primary elements is far greater

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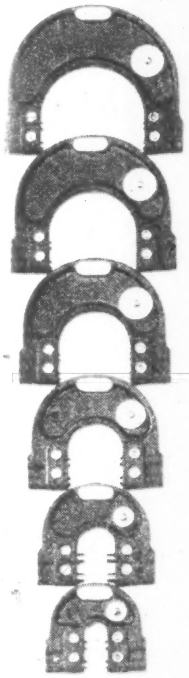

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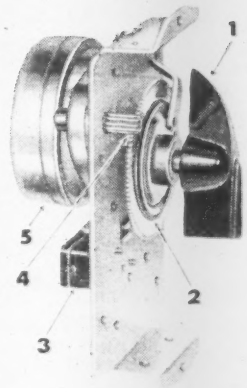

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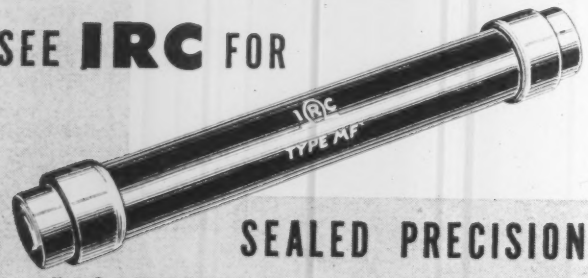

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than for Rochelle-salt elements. In order to decrease the amplification required multi-crystal pick-ups are occasionally used. The increase in potential output is roughly proportional to the number of individual crystal elements connected in series.

Since the crystal element appears to the electric circuit as a capacitance—although a capacitance having very peculiar properties (see Fig. 116A)—the effective impedance of the device increases as the frequencies involved decrease. Further, since the capacitance of a crystal element is small—only a few micro-microfarads—the effect of stray capacitances in the circuit can be extremely serious. In general the capacitance of the connecting cables employed with crystal pick-ups is comparable to that of the crystal itself, and sometimes greater. Consequently, the shunting effect of the cable, in reducing the sensitivity, may be quite large. Equally important, however, is the fact that the insulation of the cable, if exposed to shock or vibration, may introduce error through the electro-strictive effect; or it may act as a capacitative pick-up and thus likewise introduce spurious signals.

As a means of stabilizing the circuit, and reducing or avoiding the two sources of error just mentioned, it is common practice to introduce a fixed capacitance in parallel with the crystal element; part of this capacitance may be the self-capacitance of the connecting cable. The form which the circuit takes is shown in Fig. 123. The effect of this

Fig. 123

shunt capacitance is to reduce the sensitivity of the circuit to potential changes, and at the same time to reduce the effect of changes in cable capacitance.

The use of two or more crystals in parallel (and it should be noted that the two crystals in the pick-up sketched in Fig. 118B are effectively in parallel) is to decrease the impedance of the unit. Conversely, the effect of several crystals in series is to increase the impedance—it is just as though an equal number of capacitors were connected in series. And, in the normal manner for electric circuits, the shunting effect of the cable and any other parallel capacitance is in inverse proportion to the capacitance of the circuit. For this reason, when multi-crystal elements are used, it is advisable to make the connecting cables as short as possible, or to introduce an impedance-transforming device.[272] Where possible, it is advisable to use crystals of large area, or mosaic layers of similar crystals, with the total force increased in proportion to the area.[278]

The amplifiers used with crystal-type primary elements may be of any desired type, provided only that the degree of amplification be sufficient and that the input circuit be designed to operate from devices of extremely high impedance. The frequency response of the entire system depends primarily upon the design of the amplifying system. When

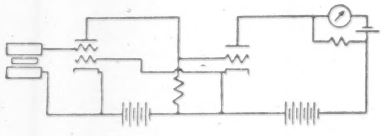

Fig. 124

extremely low frequency response is required, direct-coupled amplifiers can be used.[268] With such amplifiers, high amplification is difficult to obtain, and in order to compensate for this deficiency multi-crystal primary elements are often used. A circuit used in applications of this sort is shown in Fig. 124.

A major source of difficulty in the application of piezo-electric gaging elements is electrical leakage. It is not physically possible to establish a circuit having infinite resistance between the sensitive element and ground; elaborate precautions are taken—such as the use of the quartz itself as insulating material, as in Fig. 118—but still the

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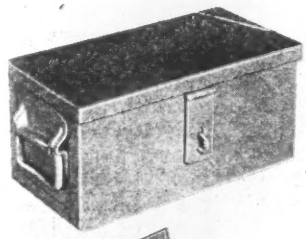

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1025- 9	18	15	9
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1025-11	18	15	12
1025-12	18	12	12
1025-13	18	18	12
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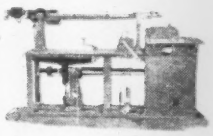

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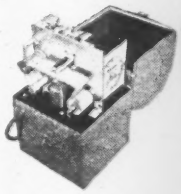

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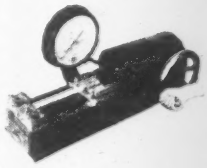

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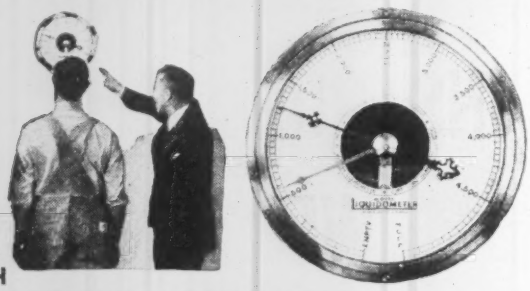

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resistance between the insulated electrode and the unins- lated one will be of the order of 50 to 1,000 megohms. T effect of this leakage is to reduce the low-frequency respon of the system, in this manner:

When, through the application of a force to the pie electric crystal, an electric charge is produced and appl to the insulated electrode a potential appears at the amp fier input. This potential is equal to the electric cha divided by the electrical capacitance of the circuit, in acco ance with the usual formula, $E = Q/C$. But because of t potential difference existing between electrodes, current w flow along all leakage paths. As this current flows, the p tential difference will of course decrease, and in a logarit mic manner; at the end of a period of time equal to t product of the resistance and the capacitance (in ohms a farads) only 63% of the original potential will rema Engineering accuracy requires that the time constant of t circuit be at least three times as great as the period of t lowest frequency being measured. Thus, to measure f quencies as low as 10 cycles per second, the time consta should be at least 1/3 second; if the capacitance of the p mary element is 300 micro-microfarads the leakage resi ance should be at least 1,000 megohms. This is a value di cult to maintain in test conditions.

§ 4. Sources of Error.

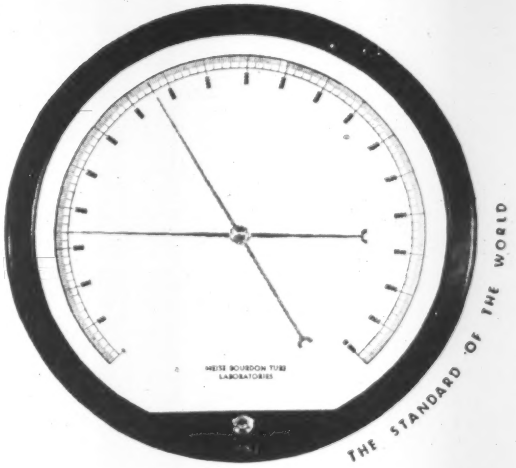
The principal sources of error in the application of piez electric measuring elements are in the electric circuits. Sin the small magnitude of the signals produced by the prima elements necessitates the use of amplifiers, changes in t amplification of the system will introduce errors in propo tion to the magnitude of the changes. Frequent checking of the amplifier gain, and careful stabilization of the circui used, provide the only solution to these problems.

Another separate source of error, frequently overlooked but quite fundamental in its nature, is that produced by changes in the capacitance of the connecting cables and the input circuit of the amplifier. Since the potential appearing at the amplifier input is inversely proportional to the ca- pacitance (other things being equal) any change in this capacitance will introduce an error which will be difficult to check. This source of error can be minimized by placing a relatively large capacitance in parallel with the crystal element and the connecting cable. If unusually long cables are used, they should be calibrated to determine the exact value of the shunting effect each produces.

The input circuit of the amplifier proper may at times introduce either of two types of errors—one of magnitude, due to the input capacitance of the electron tube, and one of frequency, caused by leakage either in the electron tube or in the electrical connections to it. The effect of parallel capacitance, and that of leakage, has already been de- scribed.

Piezoelectric elements are somewhat less subject to changes in sensitivity from outside influences than most other types of primary elements, yet such errors can and do occur. Changes in temperature will change the piezo- electric constant of the material—the amount of electric charge produced per pound of force applied. Different work- ers report widely differing values for these changes; it seems fairly well established, however, that quartz loses only a few percent of its sensitivity up to temperatures approach- ing 300° C., at which temperature it changes from the alpha to the beta form and loses almost all piezoelectric activity. It will re-convert when it is cooled to room temperature, and will again be usable. Rochelle salt crystals show a much wider variation in sensitivity with temperature change; the exact figures should be procured from the manufacturer of the crystal element—and cannot be used at temperatures higher than about 125° F., at which temperature they dis- solve in their own water of crystallization and are destroyed.

As a general rule, it may be said that when piezoelectric elements are used for quantitative measurements, great care must be taken in the design and application of the equip- ment, and frequent and careful checks must be made upon its characteristics.



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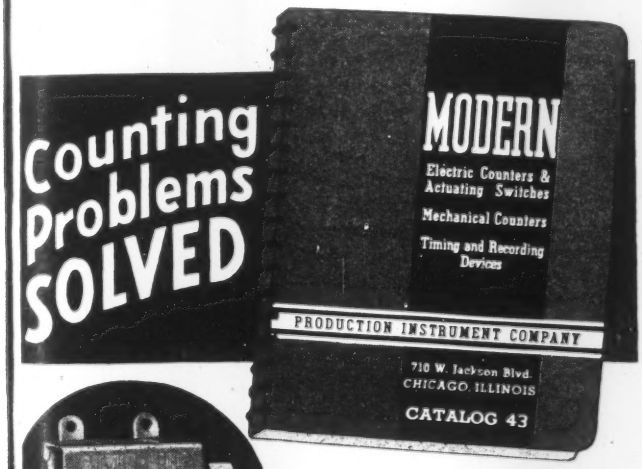

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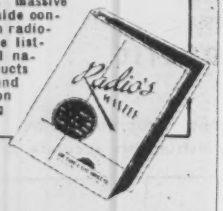

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Applications of Electronics to Process Instrumentation

Continued from Page 148

Discontinuous.—This type derives its name from the fact that the electronic output operates relays rather than the load itself, as shown in Fig. 6. The smooth stepless control provided by electron tubes has been sacrificed in favor of economy. Whether or not amplifiers are used, the relay type is characterized by a fixed dead band represented by twice the pick-up current for either relay. Although dead bands may be desirable to minimize hunting in some applications of automatic control, the fixed characteristic limits the application of this type. It is principally used for those remote applications of pre-set valve operations and remote positioning of a controller element in response to some manually-adjustable transmitter. The relays may operate secondary contactors in such manner that an unlimited amount of power may be controlled with a minimum of electronics.

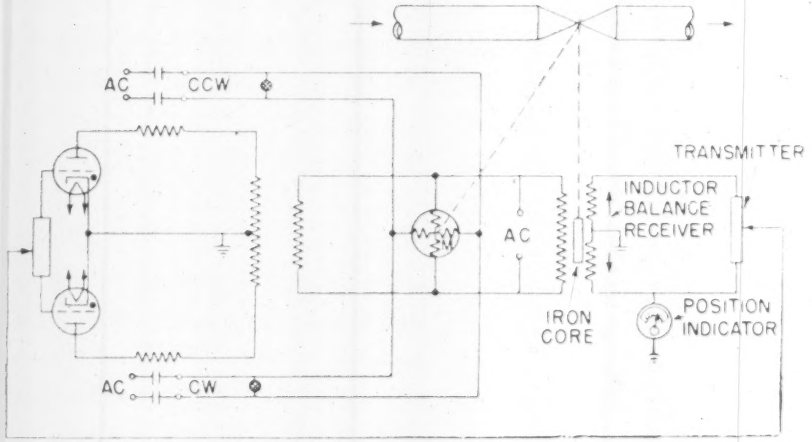

Fig. 6. Circuit of an electronic-relay type self-balancing inductance bridge.

Continuous. — The continuous type of electronic self-balancing potentiometer is one of electronics' greatest contributions to process instrumentation. It is a versatile basic measuring circuit which, with minor adjustment and auxiliaries, can be capable of measuring practically all process variables and instituting any form of control.

Basically it is nothing more than an a-c. amplifier having a motor field for its load. The motor may be either a-c. or d-c. Its primary function is to drive a variable resistor, reactor or capacitor in the measuring circuit to restore the minimal input to the amplifier. In the case of an a-c. motor, one field of the motor is supplied directly from the line; in the d-c. types, the line a-c. is applied to two plates of the output tube. In each case the a-c. serves as a reference to determine the proper direction of rotation.

A typical example of the a-c. electronic potentiometer is the "Pyrotron" developed by the Bailey Meter Company. It was developed primarily for use with a platinum resistance thermometer for temperature instrumentation applications, as shown in Fig. 7. The sensitivity of this system is such that the motor will respond to a primary-element temperature change of 0.025°F. Fig. 8 shows the amplifier

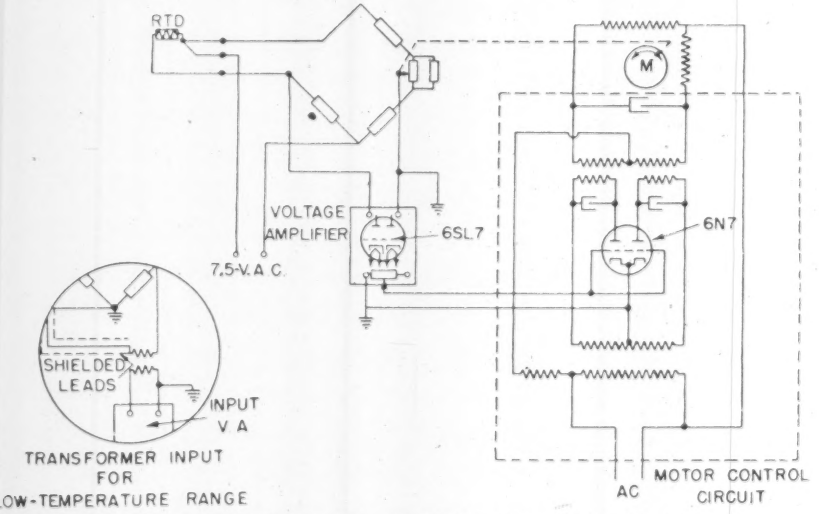

Fig. 7. Circuit of "Pyrotron" electronically-piloted self-balancing bridge used with resistance-thermometer primary element (RTD).

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T-694	H-694	0-111	135

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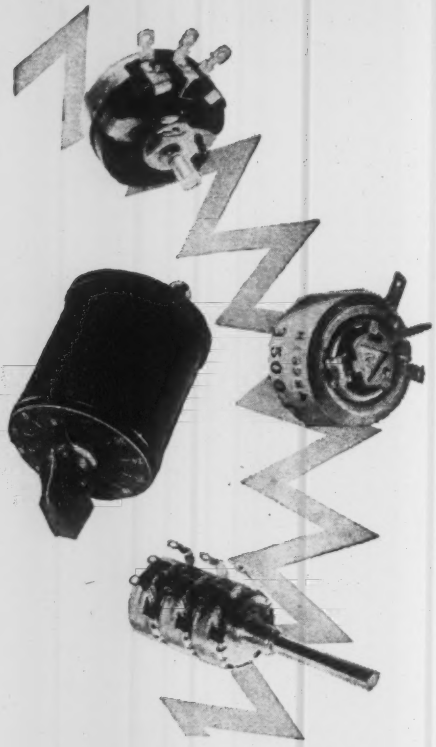

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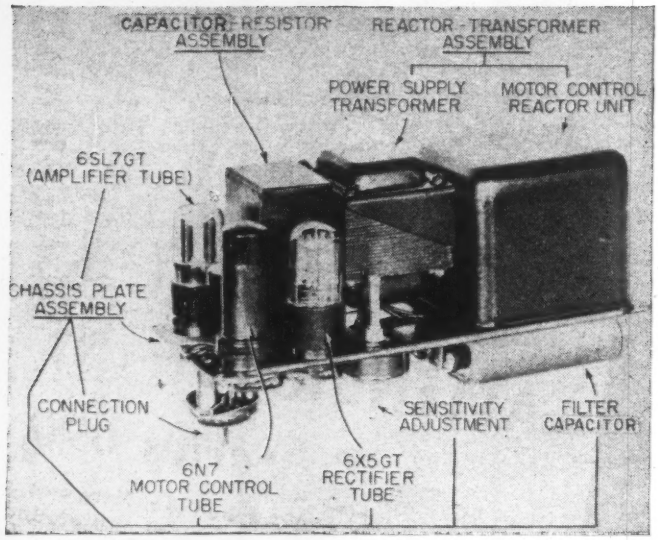


Fig. 8. Amplifier unit of "Pyrotron" self-balancing resistance bridge.

unit with cover removed and major assemblies indicated. The two stages of voltage amplification of the 6SL7GT are 50 per section or 2500. The motor will respond to an input voltage of 0.0004. On a pressure primary element, this represents about 0.00005" of motion. For a longer stroke telemeter like a flowmeter transmitter, this may be equivalent to 0.0002" of motion. With transformer input, the motor sensitivity becomes 0.00003 volt.

Such a packaged electronic potentiometer is extremely flexible and, when used with proper primary elements, is useful for a wide variety of a-c. instrumentation applications such as temperature, pressure, flow, liquid level, position, etc. The output or balancing motor has approximately 140 oz.-in. of torque which is adequate for performing a number of simultaneous functions, such as driving an instrument pointer, a recording pen, a pneumatic, hydraulic, mechanical or electric controller. This flexibility is essential to fill a wide variety of instrumentation applications. The limit of flexibility of this system is the fact that it is not applicable to d-c. measurements.

When we think of d-c. measurement, we think of the galvanometer—the cornerstone upon which electrical measurements and later automatic control of industrial processes was founded. The galvanometer was and continues to be the foremost detector of direct current and as such has always been an integral part of a potentiometer.

Today, however, we find the picture changing. Electronic equipment incorporating galvanometers is in most cases limited in its application by its speed of response and its sensitivity to off-level and vibration. Since a-c. electronic amplifiers are simpler, more practical and stable than the d-c. direct-coupled variety, it is logical that means should be developed to invert the d-c. signal and eliminate the galvanometer.

There are to date a variety of inverter devices, none of which has the inherent sensitivity or accuracy of the galvanometer, but many of which are satisfactory for the majority of process measurement applications. They take the forms of motor-driven choppers, vibrators, carbon piles, reactors and nonlinear resistors. The inversion in general, takes place at line frequency.

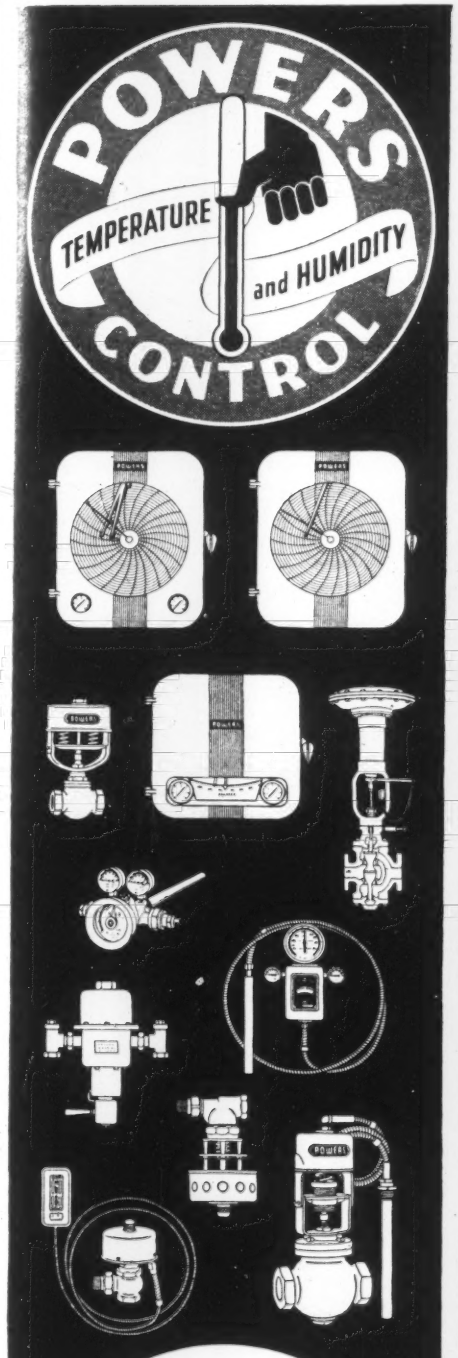
An inverter coupled with the a-c. amplifier and motor combination of the "Pyrotron" type would thus become a means for measuring and controlling d-c. process variables such as temperature, pH, vacuum, etc.

CONCLUSION

Though electronics promises much for the future, electronic instrumentation is not expected to displace the existing forms to any predominant extent. Its rise, however, will be steady as a result of the variety of instrumentation open only to electronics. It has augmented and expanded the electrical method and made its position prominent and secure. It will coöperate with other classes of controllers (such as pneumatic) to make available forms of measurement and control hitherto solved only theoretically.

Electronics has not only opened up entirely new vistas of processing possibilities but has given each process new unity in instrumentation. It has torn away the barriers to optimum process apparatus design. It has shown by performance that the failure of other instrument types to perform and often blamed on process factors can often be remedied by high instrument sensitivity and controller response. In this regard, it will serve as a stimulus to other forms of instrument design.

That the future of electronic instrumentation is secure is attested to by its rapid growth to prominence. Its future applications will become more diverse as time goes on, being limited only by the ingenuity of man to find new jobs to be done and devise new methods to do them. Electronic instrumentation is the "second wind" to automatic control.



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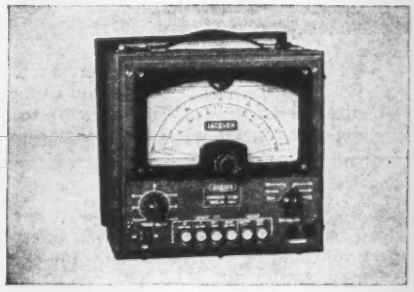
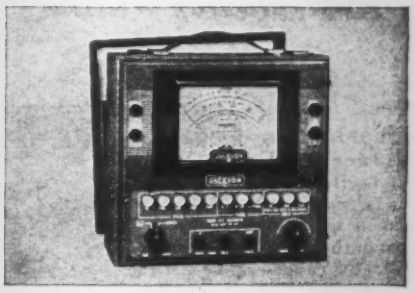
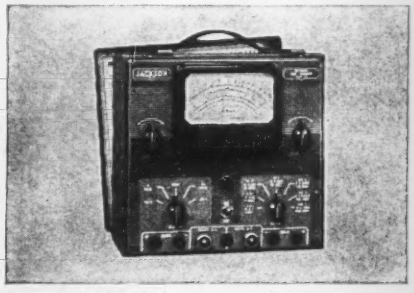


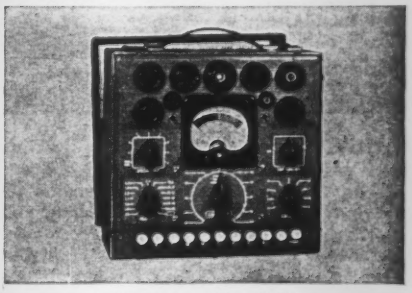
Condenser Tester—Model 650A.
Measures Capacity, Power Factor and Leakage



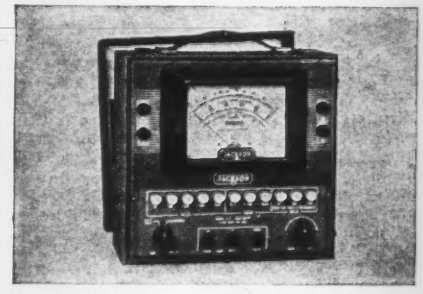
Sensitive Multimeter—Model 642.
20,000 ohms per volt—complete ranges



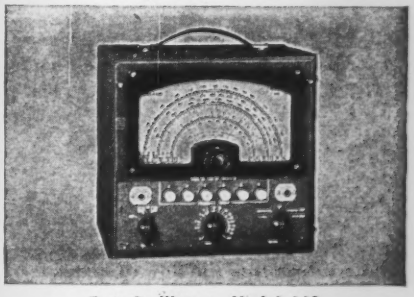
Electronic Multimeter—Model 645.
A *new* Jackson instrument of advanced design



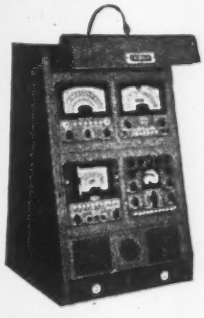
Tube Tester—Model 634.
Uses exclusive Jackson "Dynamic" Test Method



Multimeter—Model 643.
1000 Ohms per volt. Push key range selection



Test Oscillator—Model 640.
Accurate to ½% covers full frequency range



"Service Lab"
Assembly of *Standard-Size* Jackson Instruments

YES, TEAMWORK is needed to test and service a radio set. No one instrument, of course, can do the full job. Each Jackson instrument is a specialist, yet a member of the team—each outstanding in accuracy and performance, and each backing up the other.

Every Jackson unit is separate and complete. And besides being matched in quality and performance, the instruments shown here are uniform in dimensions, appearance and finish. They can be assembled in any combination you choose—as in the Jackson-built Service Lab illustrated (left). Whether you need one, several, or a complete set of instruments, *buy for the future—with Jackson.*

BUY WAR BONDS AND STAMPS TODAY

JACKSON

Fine Electrical Testing Instruments

JACKSON ELECTRICAL INSTRUMENT COMPANY, DAYTON, OHIO

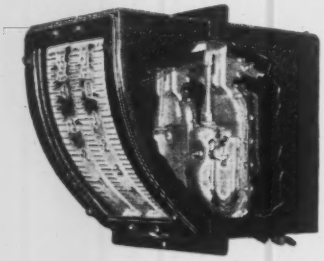
BAILEY METERS

METERS and CONTROL
for Boiler Room Service . .

Boiler Meters Reduce fuel costs, lessen maintenance and outage, lower standby costs, and add capacity. They indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-14

BAILEY METER • COMPANY •

1041 Ivanhoe Rd., Cleveland, Ohio

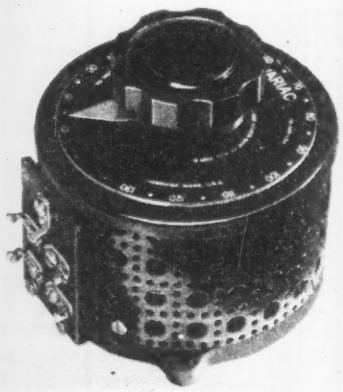
BAILEY METER COMPANY LTD., MONTREAL

The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

400-cycle "Variac"

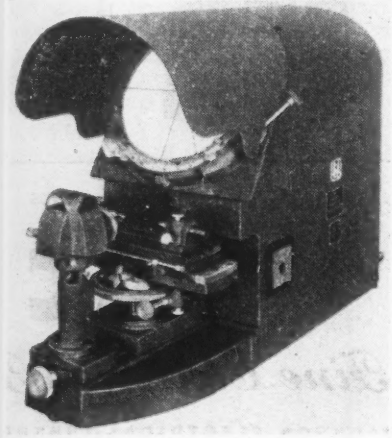
New "Type 60-A," latest addition to General Radio line of "Variacs," is a 400-cycle 5-ampere model for 115-volt use. Rated nominally at 400 cycles, this Variac can be



used at any frequency between 400 and 2600 cycles. Rating is 860 volt-amperes. Output voltages up to 135 volts are obtainable with 115-volt input. A new type of brush and radiator construction is used so that brushes, when necessary, can be changed in a few seconds. New Variac is available either with or without case. Overall height 4⅛", overall diameter 5½". Net weight 3½ lbs. cased, 3 lb.-2 oz. without case.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

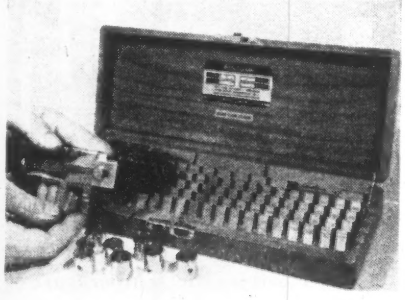
Optical Comparator and Measuring Machine

New 14" Universal Bench Optical Comparator and Measuring Machine has a table 16" long that allows measurements of lead and spacing up to 2" to be made. A handwheel graduated in 0.0001" operates on a hardened and ground thread spindle for making vertical measurements up to 1¾". A ball thrust bearing with hardened plate is incorporated in handwheel to assure ease of operation. On one end of table is a vernier segment with provision for compounding the table 15° either side of center, for projecting hobs, worms and threads normal to their helix angle. An Angle Measuring Attachment is provided for measuring angles in degrees and minutes. Maximum height of lens above table is 3" and centers are available for staging objects up to 3" in diameter by 11" in length. Other fixtures which may be used with this machine are: Vise Stage, Right Angle Stage, 1" V-block and Reflection attachment. Lenses available for this machine are: 82-mm. lens system to project a 1.4" area at 10×; 46-mm. lens system to project a 0.7" area at 20×; 48-mm. objective—with 10× ocular to project 7/32" at 62½× or with 8× ocular to project 9/32" at 50× or with 5× ocular to project 13/32" at 31¼×.—*Jones & Lamson Machine Co., Springfield, Vermont.*



118-piece Set of Gage Blocks

New "No. 118 DoALL Gage Set," also known as "Master Series," is designed for the gage department that requires a complete set of gage blocks. This set is said to be capable of producing any combination of sizes required in precision measurement: it makes possible "the widest range of combinations of any gage set on the market." It is said to serve for five distinct



applications: (1) Well represented by so-called thin blocks, one series in steps of 0.0001" from 0.010" to 0.090", a second series in steps of 0.001" is from 0.021" to 0.029", a third in steps of 0.0001" from 0.0201" to 0.0209". (2) Well represented by standard gage sizes: in steps of 0.0001" from 0.1001" to 0.1089", in steps of 0.001" from 0.101" to 0.149"; 0.050" from 0.100" to 0.950"; and inch series from 1.000" to 4.000". (3) A series of three fractional-size gages, 1/32", 3/64" and 1/16", combined with six of the standard blocks, makes possible a combination of every fraction in steps of 1/64" from 1/32" to 24 7/64" inclusive. (4) Inclusion of 0.01005" and 0.10005" sizes makes it possible to set-up a combination having a dimension of one-half ten-thousandths or 50 microinches. (5) Two special tungsten carbide gage blocks called wear blocks, both

.050", protect regular gages when used under conditions which might cause excessive wear. Their combination equals 0.100", thus making it easy to add or subtract this amount in making up a combination. Because of their small size, difference in coefficient of expansion is negligible. Etched markings are free from even tiniest burrs. In addition to size marking, each gage is individually etched with its own serial number so that it can always be identified from similar size gages of other sets. Each block is stabilized by six cycles of annealing and freezing to —120°F. and will not change more than a few microinches over a period of many years. New 118-piece set is available in three grades of accuracy: 0.000002" for laboratory use; 0.000004" for general inspection; and 0.000008" working set.—*Continental Machines, Inc., Minneapolis 4, Minn.*

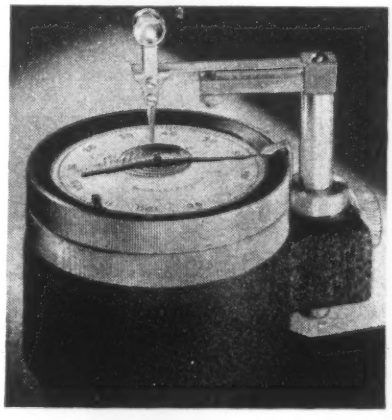
Simplified-design Sensitive Snap-action Relay

New simplified design of Type 79XAX Relay is announced, is said to meet demand for sensitive, snap-action relays for a wide variety of applications where lower cost

and ease of adjustment are important. All parts are readily accessible and sensitivity adjustments may be made easily and quickly. Armature of "79XAX" almost completes its travel in either direction before contacts snap into new position. This permits broad range of use including vacuum-tube circuits, overcurrent protection, pulsing circuits, and applications where extremely close differential or extreme sensitivity of operation is required. Standard adjustment using 60 ampere-turns in the coil at approx. 0.02 watt results in contact pressures of 5 grams with contacts rated 5 amperes, 115 volts a-c., or 0.5 amperes, 115 volts d-c., noninductive. Contact ratings up to 10 amperes, 115 volts a.c. may be obtained with 100 or more ampere-turns and a corresponding increase in power. A sensitivity of 0.005 watts with 30 ampere-turns is obtainable with reduced contact pressures and ratings. —*Struthers-Dunn, Inc., 1321 Arch St., Philadelphia 7, Pa.*

Small-spring Torsiometer

New torsiometer (produced by Sheffield as a result of collaboration with Gruen Watch Co. and Manross Div. of Associated Spring Corp.) is of comparator type, assuring precision in measuring torsion of small spiral springs. Direct readings in millimeter grams on a graduated Manross scale permit



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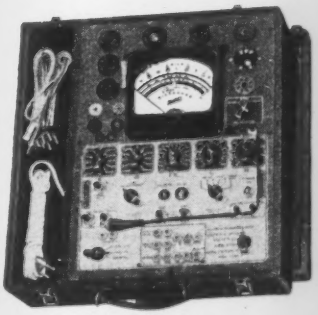
HICKOK INSTRUMENTS

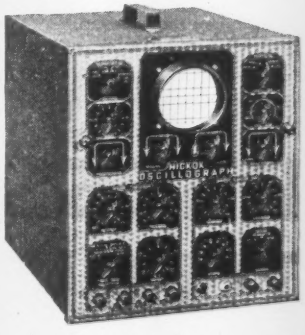
Electronic and Radio Service Equipment

Volt-Ohm-Milliammeter



All-Purpose Tube and Set Tester

Signal Generators



Oscillograph

● HICKOK Instruments have long been known as the ultimate in scientific development. Illustrated here are but 4 of our 36 leaders in the Radio Service field. Thousands of Radio Service men have preferred HICKOK Instruments because of their unusual accuracy and dependability.

HICKOK pioneered in Dynamic Mutual Conductance Tube Testing Equipment. In the field of Signal Generators, Traceometers, Vacuum tube Voltmeters, Oscillographs, Zero Current Testers, Volt-ohm-milliammeters and Industrial Analyzers the name HICKOK is assurance of excellence.

PRECISION CALIBRATED • LASTING ACCURACY

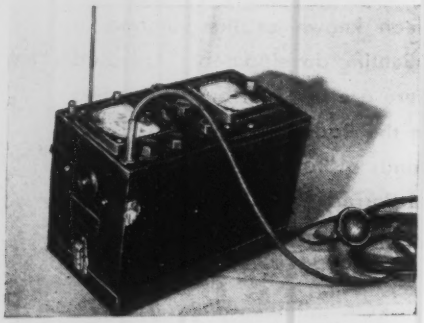
THE HICKOK ELECTRICAL INSTRUMENT COMPANY

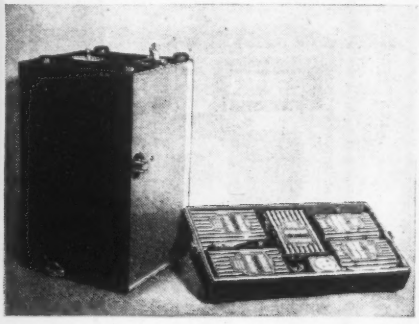
10519 Dupont Avenue Cleveland 8, Ohio

PORTABLE POWER PROBLEMS

THIS MONTH—UNITED AIR LINES' RADIO SIGNAL TEST

DIRECTIONAL INTENSITY of radio signals from all United Air Lines transmitter stations is measured at intervals with portable Field Strength Test Meters, powered by Burgess Industrial Batteries. Control of exact radiation from transmitters maintains perfect communication between ground and flight crews, assuring accuracy in guiding planes into airports.





TEST METER records full volt intensity of radio signals, showing how far and in what direction radiation extends from a specific antennae or station. Burgess Industrial Batteries are the standard of quality for commercial uses—they meet every requirement in the operation of test and control instruments. Production of industrial batteries is severely limited today by war needs, and the types you require may not be immediately available.

Burgess Battery Company, Freeport, Illinois.

BURGESS BATTERIES

ARMY NAVY

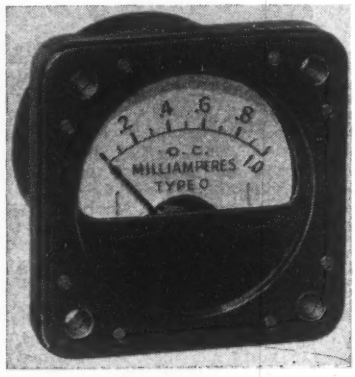
KEEP YOUR RED CROSS AT HIS SIDE!

Famous for the WORLD'S MOST COMPLETE LINE of dry batteries

classifying springs before assembling in instruments. This saves time by eliminating tedious trial assembling, disassembling, cutting, fitting, etc.; also assures a higher uniformity of quality to the products containing tested springs. New torsiometer accommodates springs up to 2⅞" diam. with a maximum torsion measurement of 49.5 mm.-g. Inner end of spiral spring to be checked is attached to center post; outer end is grasped by suspended tweezers. Outer marker is set at "120" on scale which represents "zero" point. Dial is turned one complete revolution and indicator will then give a direct scale reading of torsion. Operation is performed quickly and simply, requiring no skill or training. The indicator spindle rides on a jewel bearing and has a resistance of nearly zero. Pointer is made of non-magnetic material and pointer assembly is statically balanced. Instrument's high accuracy is indicated by its consistent repeat readings. In addition to effecting savings in instrument assembly costs, new torsiometer enables spring manufacturer to supply springs of uniform quality in each classification specified by customer. In turn customer can set up standard spring specifications and be assured that there will be little or no variation.—*Sheffield Corp., Dayton 1, Ohio.*

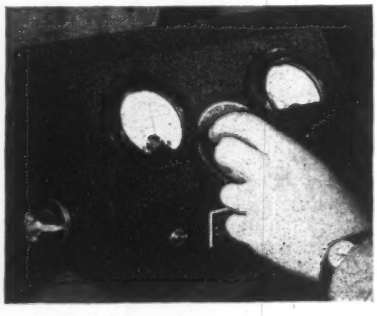
Electrical Instruments

New line of 1½" electrical instruments has been designed to withstand extreme conditions of temperature, humidity, vibration and shock in aircraft service. Instruments have been fully tested to prove their ability to maintain a service accuracy of 2%. Immersion tests have shown their ability to withstand hydrostatic pressures up to 14.7 lbs./in.² without case leakage. These new 1½" instruments are available in d-c. voltmeters in all practical ranges above 50 millivolts, and in d-c. ammeters in all practical ranges above 500 microamperes. For certain applications lower ranges can be supplied.—*Roller-Smith, Bethlehem, Pa.*



Continuous-indicating Vacuum Gaging System

New "Type E1 Thermocouple Vacuum Gage and Control Unit" combines an all-metal thermocouple vacuum gage, together with its associated control unit. Vacuum



gage is said to be featured by extreme ruggedness of construction and is assembled in a metal envelope. Connection to the vacuum system is made through a standard ¼" IPS shank pipe nipple. Illustration shows control unit, which operates directly from 110-volt a.c. and continuously indicates pressures in the range between 1 and 1000 microns. Gage output indicator is calibrated directly in microns. New gage and associated control unit provide a good method for locating leaks in vacuum systems. For this purpose spray parts suspected of leaking with acetone or ether. If a leak is present, a sudden increase in the apparent pressure reading will occur.—*The Vacuum Engineering Division, National Research Corp., Boston 15, Mass.*

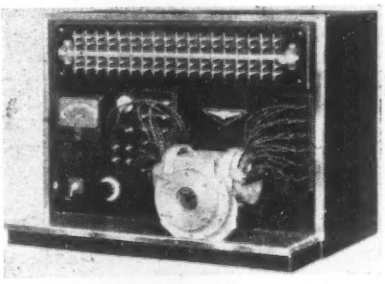
Plug-in Encased Relay

New relay of plug-in form is enclosed in a metal can and fitted with a standard octal plug base. Relay mechanism is encased in a cylindrical metal housing 2 1/16" in diam-

eter and 3 1/8" high. It is rigidly supported against shock by means of a key in the center of an insulating disk that fits snugly in top of case. Relay, made to operate on standard voltages up to 115 volts, a.c. or d.c., is a modification of a popular type of unit used in small radio transmitters, aircraft control circuits, and similar applications where space is limited. D-p.d-t. contacts are rated 4 amperes at 115 volts, 60 cycle a.c., and at 24 volts, d.c., ½ ampere from 25 to 115 volts, d.c.—*Ward Leonard Electric Co., 38 South St., Mount Vernon, N. Y.*

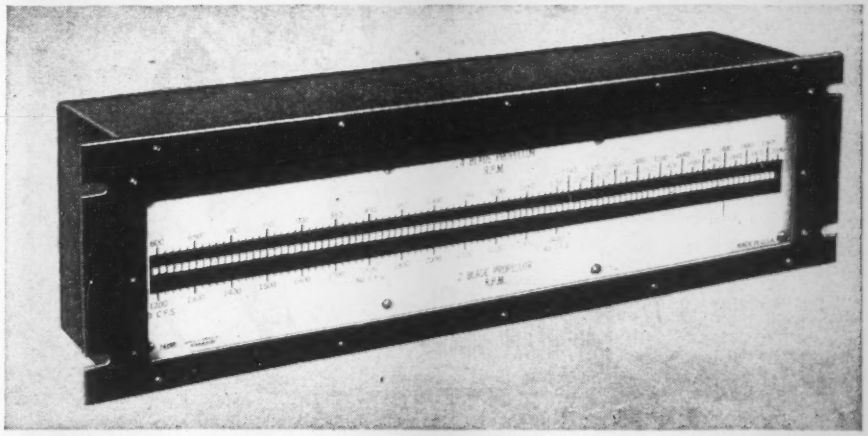
Magneto Test Stand

New "Model PA 905" magneto test stand has been designed to drive dual distributors with the magneto. Flange mounting magnetos with integral distributors may be



mounted and tested at required speeds. Magneto is directly driven and distributors are gear-driven from main drive: no error-producing pulleys and belts. Single control permits quick speed changes, armature control automatically switching to field control after basic speed is reached. D-c. driving motor is said to have these advantages: magneto speed may be easily and accurately obtained; time and power required for acceleration are reduced; higher

"FRAHM" *Resonant Reed* INSTRUMENTS



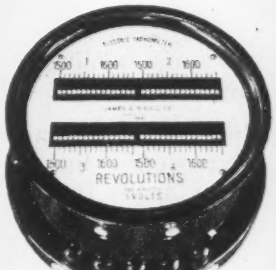
Frahm Frequency Meter with one row of 101 reeds. A recent development for a government agency.

NEW MODELS... *New Applications*

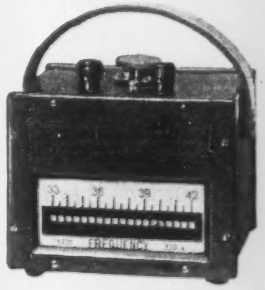
The resonant reed principle as applied to the measurement of speed, frequency and rates of vibration, first introduced in this country by Mr. James G. Biddle in 1910, has been widely adopted for a variety of services. During recent years, we have been called upon to develop units for special applications far removed from the original simple measurements of speed and frequency. Some of these special purpose instruments are shown here; some have already been standardized for regular production.

We invite correspondence regarding problems that may be solved through measurements of frequency and rates of vibration. Our accumulated experience in the development and use of Frahm Resonant Reed Instruments should prove of value in suggesting an application for your particular requirements.

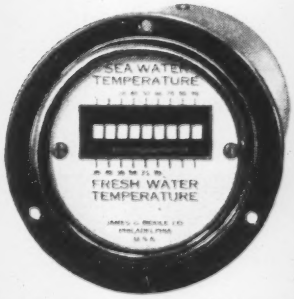
Write for Bulletin 1755-I



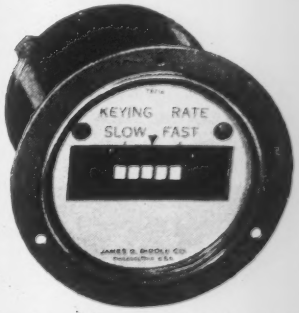
Frahm Electric Tachometer, 4 groups of reeds in the same range to aid in synchronization of the speeds of 4 engines.



Frahm Portable Frequency Meter for "series" operation in testing a special telegraph circuit.

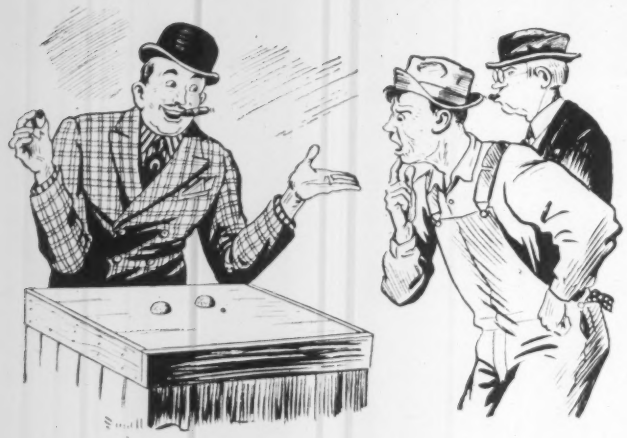


Frahm Frequency Meter used in connection with apparatus for determining temperature of salt and fresh water.



Frahm Frequency Meter for use in a special electronic circuit. Used in a device for geodetic surveying.

JAMES G. BIDDLE CO. 1211-13 ARCH STREET PHILADELPHIA 7, PA.



If you believe

THE EYE IS FASTER THAN THE HAND,

don't read this.

He who believes that the eye is faster than the hand never played the shell game!

Likewise, the manufacturer who believes that the eyes, hands and experience of his workers are better guides to profitable production than the use of instruments has never given instruments a fair trial.

THE TRAINED EYES . . . the skilled hands of experienced craftsmen cannot be discounted, but why keep them in the "horse-and-buggy" days?

THE KEENEST EYE cannot detect the difference between 108 and 115 volts in an electric circuit. Yet this difference may be the determining factor that is causing a vital manufacturing process to bog down.

THE MOST SKILLED HAND cannot detect a flaw within a casting. Yet failures caused by such defects are responsible for untold losses.

EXPERIENCE IS INVALUABLE, but the right kind of experience demands the best of help for keen eyes and skilled hands. The right kind of experience welcomes and embraces the help of instruments.

It is like the modern airplane pilot. Experience has taught him that flying by the "seat of his pants" is all right, but when it comes to flying a huge bomber over an enemy target, he depends upon the accurate, unfailing help of 250 instruments. Likewise, the smart peacetime manufacturer of tomorrow will use instruments even more than the smart wartime manufacturer of today.

Instruments

THE MAGAZINE OF MEASUREMENT AND CONTROL

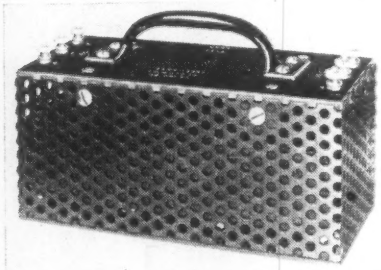
THE INSTRUMENTS PUBLISHING COMPANY • 1117 WOLFENDALE STREET • PITTSBURGH, PA.

This advertisement was prepared for INSTRUMENTS by Fuller & Smith & Ross, Cleveland, advertising agency for Westinghouse Electric & Manufacturing Company, East Pittsburgh, Penna.

speeds are allowable by reason of inherent safety speed of the motors; direct drives can be used; much time can be saved in testing by reason of ease and quickness of changing from one speed to another; sufficient torque is available at low speed and speed is positive. New "PA 905" has a heavy welded steel frame. D-c. motor is a 1½" constant horse power unit, with speed range of 0 to 3700 rpm. No external d-c. power supply is needed as power is supplied from built-in unit. Standard external power is 220-volt 3-phase, 60-cycle a.c. Electric tachometer 0 to 5000 rpm. A-c. ammeter 0 to 2.5 amps. 36-pole adjustable gap panel. One adapter and cables and plugs for connections to gap panel and distributor blocks furnished. Booster coil and switch mounted in panel. Additional adapters can be furnished upon request. Dimensions: 40" long, 30" high, 30" deep; weight approx. 300 lbs.—*Mfg. Div., Airplane Mfg. & Supply Corp., 6853 Lankershim Blvd., North Hollywood, Calif.*

Isolating Transformer

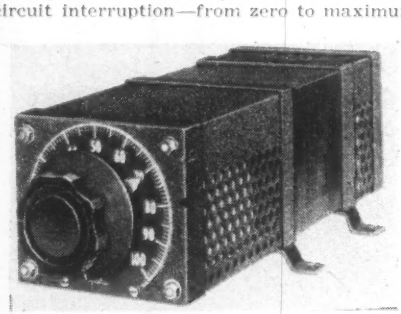
New "No. 7242" isolating transformer for use in laboratory, test, and portable applications, is wound for three-phase but may be employed on single-phase circuits. It is



said to be a compact component especially convenient for portable use, incorporating a handle carefully placed for balance. Ratings are as follows: 250 va., 115 Volts, 1:1 ratio, 3-phase. Exceptional frequency range (60 to 400 cycles) assures wide applicability in laboratory and in communication work. Construction is said to be rugged, efficient, and drip-proof. Ventilated housing is designed for maximum protection and good appearance. Transformer is 8½" long, 5½" high, 4" wide; weighs 16½ lbs.—*New York Transformer Co., 26 Waverly Place, New York 3, N. Y.*

Variable-voltage Transformer

New "Vari-Former" is said to offer extreme flexibility in a-c. voltage control. Voltage is continuously variable—without circuit interruption—from zero to maximum

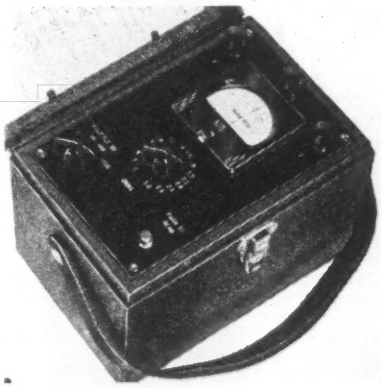


values. A self-aligning solid silver contact, fingertip controlled by a single knob switch, provides small increment voltage change throughout range of device. No carbon brushes are used. Incremented increase is in the order of 0.75 volts or less. Standard units are auto-transformer type, available wound for constant current or taper wound for current proportional to voltage. Unusual design characteristics are said to be embodied: rugged dip-proof construction, high overload capacity, conservative ratings, low no-load loss, excellent regulation. "Vari-Formers" are lighter in weight and smaller

in size than comparable units of similar ratings. All working parts, windings, etc., are protected by well-ventilated heavy-gage shell for protection from dust and mechanical damage. Windings are on shell type cores, impregnated for immunity to moisture and humidity. Control is smooth and easy-operating but sufficiently snubbed to prevent movement from shock or vibration. Mounting provides for bolting to panel, support or table mounting. Transformers have minimum stray field and introduce no radio interference. Units are supplied either with auto-transformer winding or separate windings for isolation of circuits. Available for one or three-phase use with single control. Class "A" or "B" insulation optional.—*Gelow Corp., 26 Waverly Place, New York City.*

Ground Resistance Tester

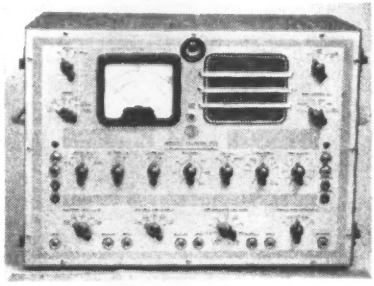
New "Model 255 Vibroground" provides a much greater range of low and high ground electrical resistance testing than did previous model. It is said to give accurate



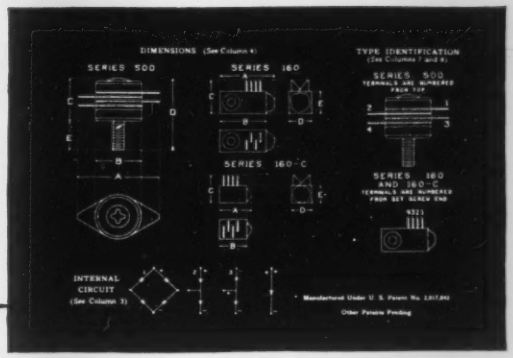
readings for all ground conditions, and to be particularly adapted to arid or wet regions or where extremes of dryness or moisture are found. It has four ranges: 0-3, 0-30, 0-300, 0-3000 ohms. It comes complete with self-contained power supply. With its direct readings no calculations are necessary. Reverse readings are unnecessary and polarization errors cannot occur. Design also excludes strays from high potential networks, d-c. ground currents, or any a-c. commercial frequencies, and other sources encountered in plant or field. It is claimed that a complete test, including setting test rods, can be made in less time than by any other means. Easily-portable one-piece welded metal case is water-tight, assuring accurate readings even on sodden ground.—*Associated Research, 231 South Green St., Chicago 7, Illinois.*

Multi-section Tester for Sound Systems

New "Type 170A Audio Chanalyst" provides complete sound system testing equipment in a single unit. It comprises several self-contained testing sections or "channels" and can be used to test any point of any sound system from microphone to speaker, serving in emergencies as a bridg-



Conant Instrument Rectifiers


DIMENSIONS (See Column 4)
SERIES 500
SERIES 160
SERIES 160-C
TYPE IDENTIFICATION (See Columns 7 and 8)
SERIES 500 TERMINALS ARE NUMBERED FROM TOP
SERIES 160 AND 160-C TERMINALS ARE NUMBERED FROM SET SCREW END
INTERNAL CIRCUIT (See Column 3)
Other Patents Pending

SPECIFICATIONS (STANDARD TYPES)

Col. 1	2	3	4					5	6	7	8				9						10
											Color, Terminal Number				PEAK ELECTRICAL RATINGS						
		Internal	Dimensions (Inches)					Mounting Screw	Weight	No. of Ter-					Instantaneous		Intermittent		Continuous		
Type	Series	Circuit	A	B	C	D	E	Size	(Grams)	minals	1	2	3	4	Volts	Mils	Volts	Mils	Volts	Mils	*List Price
M	500	1	.890	.500	.485	.800	.328	6-32	13.012	4	red	no	blk	no	30	100	20	60	10	30	$3.50
HS	500	2	.890	.500	.445	.800	.360	6-32	9.158	3	red	no	blk	—	15	100	10	60	5	30	2.70
T	500	3	.890	.500	.445	.800	.360	6-32	9.158	3	no	red	no	—	30	100	20	60	10	30	2.70
H	500	4	.890	.500	.400	.800	.392	6-32	7.730	2	red	no	—	—	15	100	10	60	5	30	1.50
B	160	1	.595	.485	.375	.250	.250	2-56	3.400	4	red	no	blk	no	30	15	20	10	10	5	3.50
BHS	160	2	.625	.550	.375	.250	.250	2-56	2.880	3	red	no	blk	—	15	15	10	10	5	5	2.70
BT	160	3	.625	.550	.375	.250	.250	2-56	2.880	3	no	red	no	—	30	15	20	10	10	5	2.70
BH	160	4	.625	.550	.375	.250	.250	2-56	2.700	2	red	no	—	—	15	15	10	10	5	5	1.50
B-C	160-C	1	.345	.297	.310	.220	.200	none	1.743	4	red	no	blk	no	30	15	20	10	10	5	3.50
BHS-C	160-C	2	.345	.297	.310	.220	.200	none	1.385	3	red	no	blk	—	15	15	10	10	5	5	2.70
BT-C	160-C	3	.345	.297	.310	.220	.200	none	1.385	3	no	red	no	—	30	15	20	10	10	5	2.70
BH-C	160-C	4	.345	.297	.310	.220	.200	none	1.293	2	red	no	—	—	15	15	10	10	5	5	1.50

Over ninety per cent of all rectifier requirements are served by 12 types—4 basic assemblies in 3 series. These 3 series are the three primary units of Conant rectifiers. Special types, however, can be developed as needed, and you'll find Conant ready to cooperate.

SERIES 500 UNITS are for general applications requiring greater output current for meters, relays or other apparatus requiring more than 1 milliampere. Recommended for all such applications at commercial and the lower audio frequencies. Will also operate up to 50,000 c.p.s. in special applications wherein accuracy of readings is not essential.

SERIES 160 and 160-C are for applications requiring good frequency response over the entire commercial and audio range and especially when the meter, relay or other apparatus requires less than 1 milliampere for operation. In some special applications these units may be operated at frequencies up to 15,000,000 c.p.s. with special circuit treatment.

SPECIAL TYPES are available in both series 500 and 160-C. When requesting a quotation on a special type include a sketch of the rectifier required or a circuit diagram showing source and frequency of the input voltage, resistance and kind of load, required load current and the ambient temperatures.

SERIES 500 Disc diameter .500 inch. Area each disc .15 square inch. Furnished with 3" braided, tinned copper leads. Finished in clear lacquer. Nickel plated end plates.

SERIES 160 Disc diameter .160 inch. Area each disc .02 square inch. Furnished with 3" stranded, tinned double silk covered copper leads. Nickel plated case. Assembly sealed with specially developed moisture proof compound.

SERIES 160-C Disc diameter .160 inch. Disc area, lead wire and length and moisture proof seal are identical with Series 160. Dimensions of the nickel plated case have been reduced to the most compact size. These units may be mounted in a standard midget fuse clip.

Conant Instrument Rectifiers are available from leading radio jobbers everywhere—consult your local jobber.

CONANT *Instrument Rectifiers*

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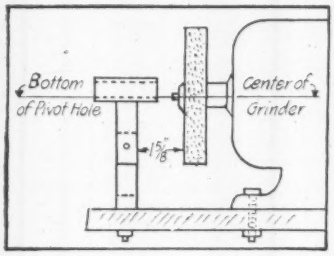
New Quick-set Dial Drill Sharpener Eliminates Guesswork...Keeps 'em Drilling Faster—Longer

Attached to the Drill Sharpener, it adjusts drill edges to the proper angle for precision grinding, putting drill sharpening on a quick, efficient basis.

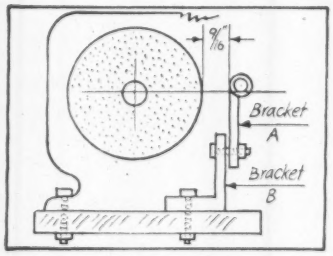
QUICK-SET DIAL easily and accurately adjusts Sharpener for sharpening drill from 5/32" to 1" sizes. Dial insures accuracy in measuring angles and clearances on twist drills, preventing trouble and making drills last longer. Dial-Set sharpened drills cut faster and more accurately, as the edges are alike and uniformly sharpened.

Precision built, calibrated and tested, unit is easy to set up and operate. Saves wear and tear on drill presses—prolongs drill life—cuts costs—improves quality—speeds output.

Another thing worth remembering is Wrigley's Spearmint Gum. That familiar red, white and green package which always meant "a help on your job." No more of this famous brand and flavor is being made for anyone now—even for the Armed Forces overseas—as Wrigley's stockpile of finest quality raw materials is all used up. But—remember Wrigley's Spearmint—The Flavor Lasts.



Front view of grinder



Side view of grinder

You can get complete information from Ameraco Industrial Specialties, 122 S. Michigan Ave., Chicago 3, Ill.

Z-59

To the Engineer, Physicist or Chemist Who Seeks A PERMANENT JOB

IF YOU are an engineer, physicist, or chemist now working for a company whose war contracts are terminating there may be a permanent job for you with one of the leading instrument manufacturers. Most of these companies are still working full time on war work. As soon as their war contracts are completed, postwar projects will be ready for action with plenty of opportunity for creative development work. Interested? Write Employment Service, Instruments Publishing Company, 1117 Wolfendale St., Pittsburgh 12, Pa., giving complete professional and personal data. U.S.E.S. consent and release statement will be required.

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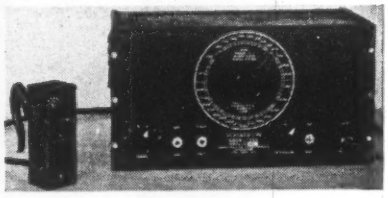
ing unit to substitute for the defective section of an inoperative amplifier. Unit contains a calibrated high-gain amplifier useful for signal tracing, tube checking and gain measurements. It supplies its own test signal from a built-in beat-frequency oscillator which can be operated by an internal auxiliary sweep circuit for checking multiple speaker installations. Maker's "Vol-Ohmyst" is included as one of the channels and it has been modified for flat, linear measurement of audio frequencies. An impedance tester and a high-speed "electronic indicator" add to unique testing facilities of "Audio Chanalyst," as various combinations of its channels can be used for audibie and visual testing. Initial production supplies largely to Armed Forces; civilian supply governed by priority ratings.—*RCA Victor Div., Radio Corporation of America, Camden, N. J.*

Stroboscope

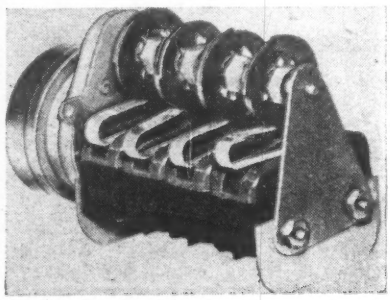
New "Model 1200" stroboscope is said to be based on a "completely new principle" and is claimed to increase the range through which moving objects may be examined.



Rotary speeds from 600 to 600,000 r.p.m. or vibrations from 10 to 10,000 c.p.s. can be "stopped" and studied. Light source being mounted in a small probe at end of a 5-ft. flexible cable, small objects may be easily viewed at close range. Provision is made to operate unit from external tuning-fork or crystal standards, where extreme accuracy is required. Motion of objects moving at irregular speeds may also be "stopped" with "Model 1200." An accurate repetitive pulse rate is said to be obtained by pulses derived from a stable audio oscillator, obviating need of constant readjustment of repetitive rate and insuring clearly-defined images at high speeds. A light intensity control switch is also provided for greater flexibility; this enables user to control both light intensity and pulse-length duration. — *Communication Measurements Laboratory, 120-24 Greenwich St., New York City.*

Fixed-interval and Repeat-cycle Timers

New "No. 5800 Series" is a complete line of continuous running repeat cycle timers with either a-c. or d-c. operation. Illustrated is "No. 5800-4" (four circuit) a-c. motor-driven unit. New timers are available with one to eight switches as required by customer. Appropriate motor speed is selected (most popular speeds from 8 rpm. down to 1 rev. per month), according to timing cycles desired. If the occasion arises, maker can adjust motor to one rev. per six months. Precision snap switches are used, single or double throw, 10-amp. capacity at 110 volts a.c. Assembly illustrated shows adjustable



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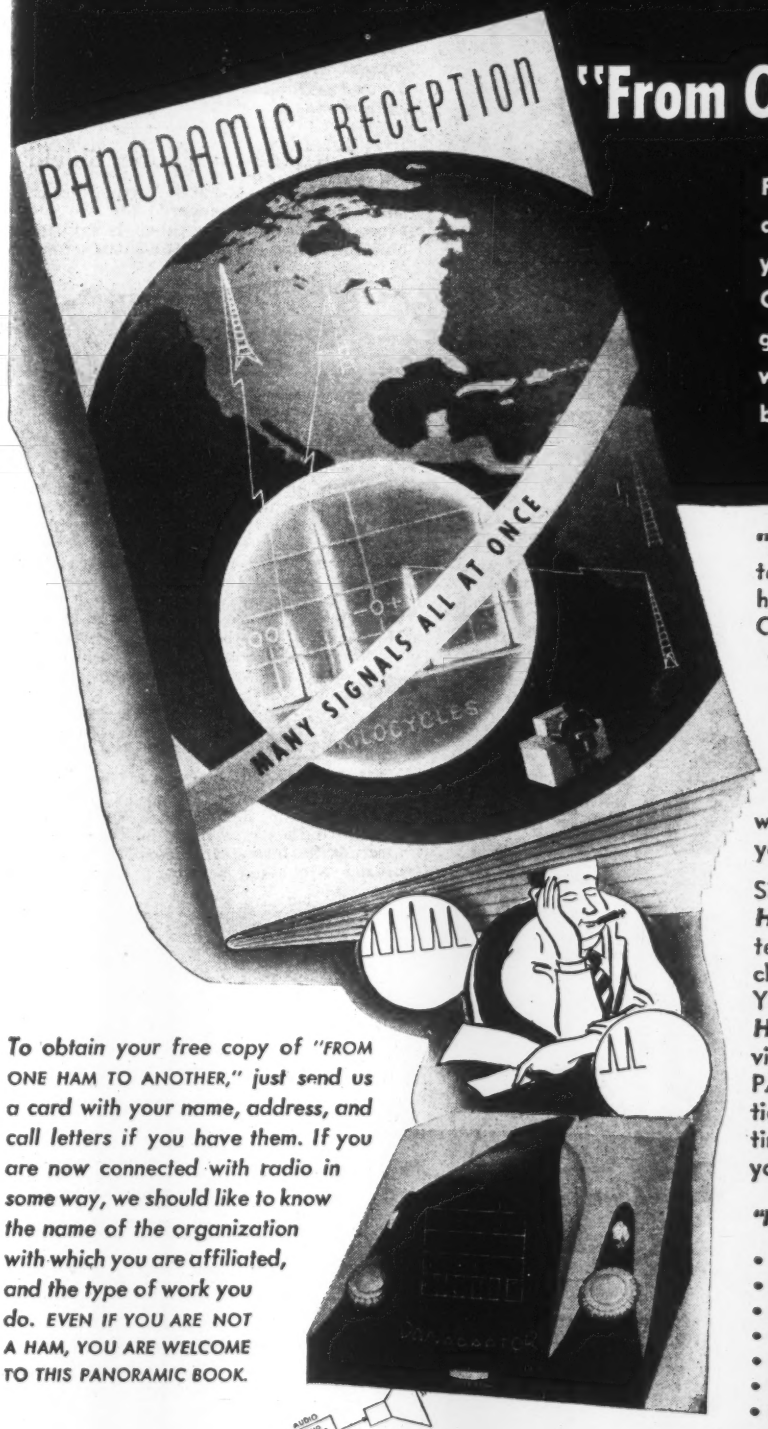

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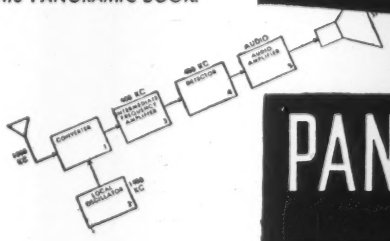

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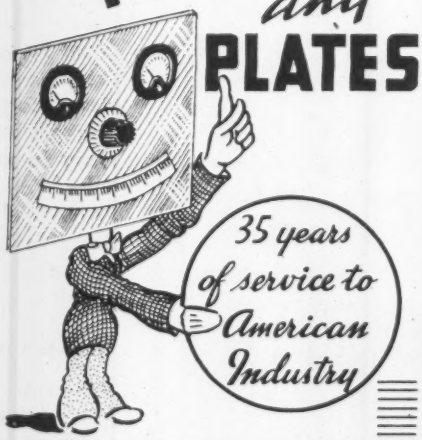

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cams which can be set to throw the switch from 1° to 180° of the revolution. Specially-cut cams are also available for various combinations of "on" and "off" cycles covering a range from more than one actuation per second down to one per month. New timers are available on various commercial a-c. voltages and frequencies as well as on d.c., wide range of motors being secured through Haydon sealed-in lubricated gear trains. They are designed to meet any desired pattern of electrical impulses in virtually any overall interval for radio keying, industrial timing, process control, sequence switching, etc. Also available with brake for instant stop for end of single cycle if so desired.—*Haydon Mfg. Co., Box 52, Forestville, Conn.*

Cathode-ray Tube Shield

New "Model M-996g" cathode-ray tube shield has been engineered for use with all three-inch cathode ray tubes, is said to combine shielding essential to satisfactory per-

formance with convenience of both panel and chassis mounting. Protection against vibration and shock is afforded by shock-absorbing cushion built into clamp ring and by gum rubber gasket around tube face. Mechanical protection for tube is provided by transparent screen, available in either plain or colored Lucite. Shield body, formed of Mu-metal, is cadmium plated all over, with black baked wrinkle outside finish. New shield can be furnished with design modification to suit special requirements.—*Metallic Arts Co., 243 Broadway, Cambridge 39, Mass.*

Aviation Battery Tester

New High-rate-discharge Battery Tester ("Model 666" and "Model 667") has been developed for ground use for conducting high-rate-discharge tests on Army and Navy aircraft batteries. It incorporates five calibrated Nichrome resistors, capable of dis-

sipating up to 350 amperes on batteries of 12- or 24-volt potential. These resistors are selected by means of five thrust-type terminals and battery connections are by means of two heavy cables. When switch is thrown to start test, an aircraft relay simultaneously closes main-load circuit and actuates a solenoid-type relay to start a time clock which indicates elapsed time, automatically corrected for temperature of battery and specific gravity of electrolyte. A combination voltmeter and ammeter is

ounted in "Model 667" tester, while in "Model 666" only the voltmeter is available. hen voltage drops to 14.4 volts on a 24-lt battery, or to 7.2 volts on a 12-volt bat-ry, switch is thrown off and elapsed time ad. In "Model 667," it is also possible, rough use of ammeter switch, to quickly ad the current-flow during the test. Entire st is based on current and voltage against ne. Reference to chart on lid shows at a lance the rate of discharge specified for rious types of aircraft batteries. Tester is mpact in design, withstands mechanical ocks and stresses of normal operation nditions, satisfies requirements of the rvices as well as of leading battery-manu-acturers.—*Lanagan & Hoke, Philadelphia , Penna.*

Projector-type Comparator for Replica Film Inspection

New "Model C1000 Faxfilm Comparator Apparatus" has been developed for con-enient examination and comparison of

Fig. 1

"Faxfilm" surface contact replicas (see *Instruments*, Nov. 1944, page 716). It comprises two 100-watt projectors with overhead reflectors (see Fig. 2) projecting onto an inclined inspection screen. Each projected

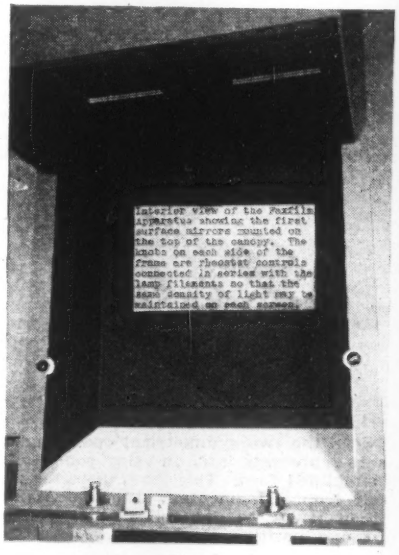

Interior view of the Faxfilm Apparatus showing the first surface mirrors mounted on the top of the canopy. The knobs on each side of the frame are rheostat controls connected in series with the lamp filaments so that the same density of light may be maintained on each screen.

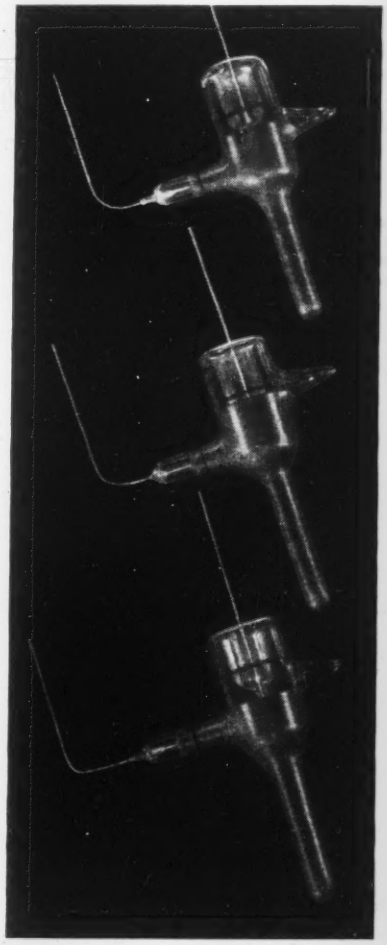
Fig. 2

Now Available...

for Research Workers in Radiology

GEIGER-MUELLER COUNTER TUBES

As designed at the University of Rochester for biological work



GEIGER-MUELLER COUNTER TUBES of the type illustrated were designed at the School of Medicine and Dentistry of the University of Rochester, and have been used there with conspicuous success. In order that they might be made available to other workers in the field of radiology, Distillation Products, Inc. undertook their construction.

These tubes respond to beta radiation, emitted by radioactive elements, through an extremely thin copper-coated glass cylinder containing gases that readily ionize under this influence. The counting threshold is about 1200 volts. Connected with a stable voltage source, electronic quenching circuit, and counting meter, the tubes give an accurate record of the proportion of radioactive elements present. They are entirely satisfactory in discerning elements tagged by the radioactive isotope in chemical and biological studies utilizing the tracer technic. Further information about the tubes, or about amplifiers and auxiliary electronic equipment, will be supplied promptly upon request. Address *Vacuum Equipment Division.*

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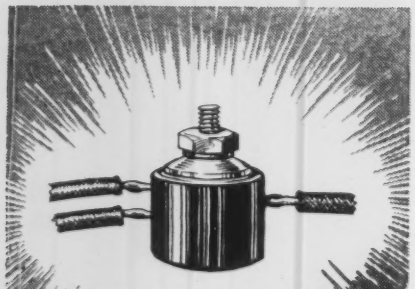
Other instruments in the G-E line of laboratory measuring equipment include: Regulated Power Supplies, R-F Capacitometer, Square-Wave Generator. Write: *Electronics Department, General Electric, Schenectady 5, N. Y.*

Electronic Measuring Instruments

GENERAL ELECTRIC

164-09



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Unique construction enables operator to rapidly determine temperature even on minute spots, fast moving objects, or smallest stream; no correction charts, no accessories, no maintenance expense. Special "FOUNDRY TYPE" and "Universal TRIPLE RANGE" have, in addition to standard calibrated range, a red correction scale determining TRUE SPOUT and POURING TEMPERATURES of molten iron and steel when measured in the open.

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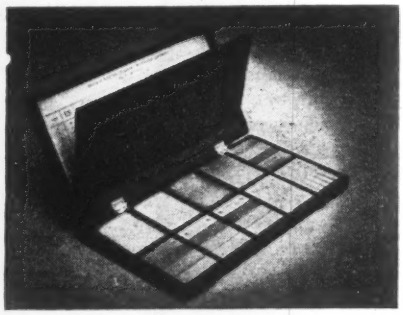
image is at 100-diameter magnification and is 20″ square. The projection table is so arranged that any part of the "Faxfilm" replica may be brought to view at any point on screen; while magnification and resolution of projected images of both standard and specimen will be equal. Framework (see Fig. 1) is 95″ high, 42″ wide and 28″ deep. Comparator weighs approx. 400 lbs. crated for shipment.—*Rex D. McDill, 5109 Mayfield Road, Cleveland 21, Ohio.*

Surface-roughness Standard Specimens

New standard surface-roughness specimens comprise a set of ten, each representing one clearly-identified degree of surface roughness ranging from smoothness of a



bearing surface to roughness of a flame cut. New specimens are designed to permit engineer or draftsman to select (and specify by symbol) degree of surface roughness allowed for a particular machine part. They also enable mechanic in shop to determine exact surface roughness allowed by drawings. Each of the ten metal specimens is approx. 2″ × 2½″ × ⅛″; several are divided into two and in some cases four surfaces, all of which, while equally rough, are produced by different machining methods. In all, the ten specimens simulate 25 surfaces, each surface representing the roughest one acceptable for that particular symbol regardless of method of producing finish, or material of which part under inspection is made. Cloth-lined wooden case, 12″ × 6″ × 1¼″, designed for protection and for convenience in handling, has a partition which holds specimens in their compartments and also protects a chart (on inside of cover) which conveniently sets symbols for ready reference. Little experience is required to use specimens efficiently, since comparison of surface under inspection with that of selected specimen is made visually and tactually.—*Special Products Div., General Electric Co., Schenectady, N. Y.*

Latch Interlock Relay

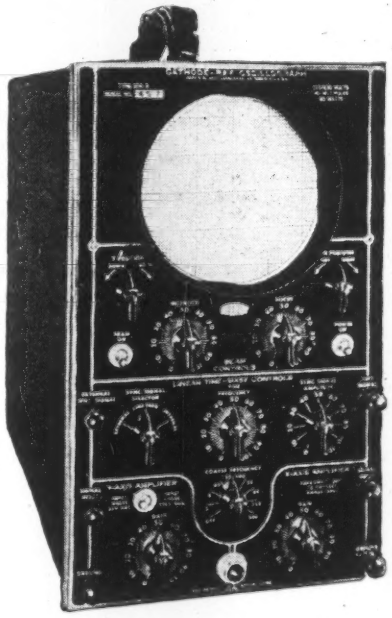
New "Series 50XBX" 2-coil relays are added to maker's "Memory" relay types, are of simplified design and meet aviation specifications. A new style positive interlock

between the two symmetrical operating elements represents latch-in relay construction in simplified form. This latch operates positively from a momentary impulse. Application of power to one coil latches contacts into one position. Power then applied to other coil throws contacts into a latch-in second position. A third "unlatched" posi-

tion, valuable for certain applications, can be obtained by energizing both coils simultaneously. New design makes it easy to obtain make-before-break, or break-before-make contact combinations. Contacts do not interrupt coil circuit until "throw" is entirely completed and contacts are locked in new position. Relays of this general type are produced in ratings from 6 to 200 amperes or more, and with practically any desired contact arrangement. Standard types provide for two auxiliary contacts, one in each coil circuit. Use of auxiliary contacts makes it possible to obtain operation over an extremely wide range of a-c. or d-c. voltages. New "Memory" Relays are small and compact. Example, "Type 50XBX103," having 2-p.d-t. main contacts, and rated at 6 amperes at 24-volts d.c. is 3 7/16" long, 1 7/8" high and 1 5/8" wide.—*Struthers-Dunn, Inc., 1321 Arch Street, Philadelphia 7, Penna.*

Cathode-ray Oscillograph

New "Type 208B" cathode-ray oscillograph is said to represent that "what happens to a laboratory instrument when it goes to war is told in design changes and refinements effected during the past two



years," wartime touches being as follows: Use of mineral-oil-impregnated hermetically-sealed paper capacitors as well as increased voltage ratings for certain paper capacitors, for greater factor of safety. Capacitors are operated at less than 80% of voltage rating, while all composition resistors operate at less than 40% of power rating. High voltage wire replaces previous standard wire in high-voltage circuits. Various changes have been made in the tube complement. There is a change of negative supply rectifier from Type 17 to the Army-Navy preferred Type 6X5GT/G; from the ¼ watt neon tube to the Army-Navy preferred Type 991 voltage regulator for greater stability; from Type 6F8G tubes to Army-Navy preferred Type 6SN7GT, with improved performance. There is now included a frequency range adjustment resistor in the time base as a factory adjustment, for accurate time-base frequency setting. For greater mechanical ruggedness there are several refinements such as mounting straps on capacitors, tube clamps, flange added on chassis assembly, better sockets, self-locking stop nuts, rolled bead on c-r. tube shield, additional brackets, etc. —*Allen B. Du Mont Laboratories, Inc., 2 Main Avenue, Passaic, N. J.*

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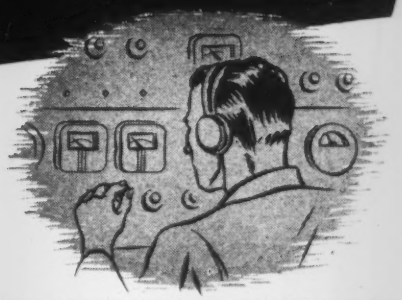

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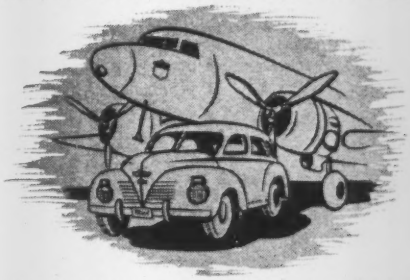
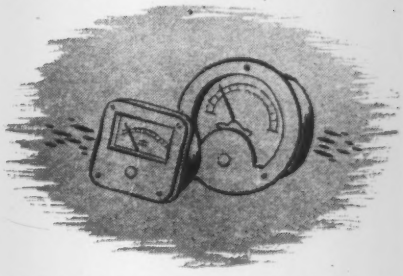


INSTRUMENTS



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ESSENTIALS OF PRECISION INSPECTION. By WESLEY MOLLARD. McGraw-Hill Book Company, Inc., New York, 1944. Cloth, 8½ × 11¼ inches. xii + 207 pages. Price $3.00.

The factor which has contributed more than anything else to the successful prosecution of the present War has been American industry's ability to produce perfectly interchangeable parts. This interchangeability has been made possible by measuring standards which have facilitated the calibration and adjustment of gages and precision measuring instruments to the same uniform degree of accuracy all over our broad United States. The development of gages and measuring instruments of greater precision has made necessary the training of people to use them. This problem has been difficult because of the scarcity of trained mechanics due to—

(a) Induction into the Armed Forces of technically trained men

(b) Suspension of all apprenticeship training programs during the great depression, during which no mechanics were trained.

Therefore, industry was waiting for a book like this. Fortunately, the author has kept the shop man in mind while writing it so that the result is an understandable work which is helpful to both the new and the experienced inspector. There is not an unnecessary word or a superfluous paragraph in the whole book.

The author gives in Chapter I a descriptive list of the more common tools used in inspection work. This enables the new inspector to get a bird's eye view of what is available and serves as a review to the older inspector. This feature alone is worth the price of the book to the practicing inspector.

The author then takes each tool and devotes one or more pages to it, with detailed instructions for its use. He then follows this text material with problems to be worked out by the student. The author covers the ground so thoroughly that no inspector should be without a copy of this book in his tool-kit. The method of treatment of the material, and the fact that the author has kept in mind the audience for which he was writing—the shop man—makes this work doubly valuable.

The author effectively removes the mystery surrounding the sine bar. However, he could have simplified the instructions for wringing gage blocks. The final cleaning operation on gage blocks should be performed by wiping them on the heel of the hand, or, better still, on the forearm. One block should then be slid over the other with pressure, with one motion, without "oscillation." Every author being entitled to make one mistake, we can forgive Mollard for this one deviation from the straight-and-narrow — which does not impair the value of the book.

His treatment of milling cutters is excellent, as are his instructions for checking them and the illustrations used to make the method clearer show that he has done a considerable amount of work on this subject.

The treatment of threads has made this otherwise obscure subject clear. The exposition is complete and covers all methods of checking threads. Anyone reading this one chapter on Threads could consider himself a good inspector, as this is one subject on which most inspectors are weak.

The author has tackled one part of inspection work which most writers shy away from, and that is "gears." Very few inspectors understand the subject of gears, methods for checking gears, and gear checking equipment. The author presents this material in a lucid, clear, understandable and complete manner.

"Essentials of Precision Inspection" is one of the few books published during the period of the War which makes a definite contribution to the science of inspection.

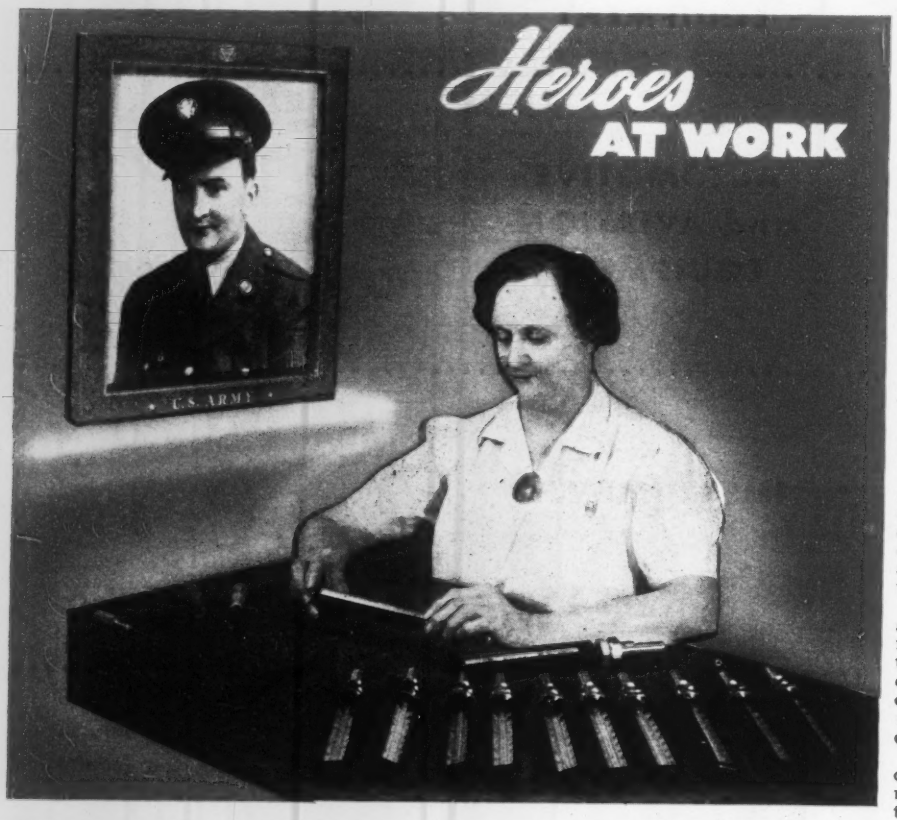
—J. MANUELE, *Director of Quality Control, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

EXPERIMENTAL SPECTROSCOPY. By RALPH A. SAWYER. Prentice-Hall, Inc., New York, 1944. Cloth, 6 × 9¼ inches viii + 323 pages; 107 figures. Price, $5.00.

While "it is designed for students of spectroscopy and for those in research laboratories who wish to make use of spectroscopic procedures", the most experienced spectroscopist is likely to find in this book some ideas which he has overlooked and so be amply repaid for a careful reading of the whole text. The subject matter is presented in such a manner that it is read with pleasure as well as profit.

The treatment of the effects of each of the possible maladjustments, and the discussion of the means of getting the best results from a grating that is slightly defective (and the best grating is likely to have slight defects), can be of great assistance to the beginner. Methods of testing spectrographs of all types are given in detail by an expert. The fundamental principles of optics are presented in sufficient scope and detail for the purpose of spectroscopy.

Chapters on prism spectrographs, and



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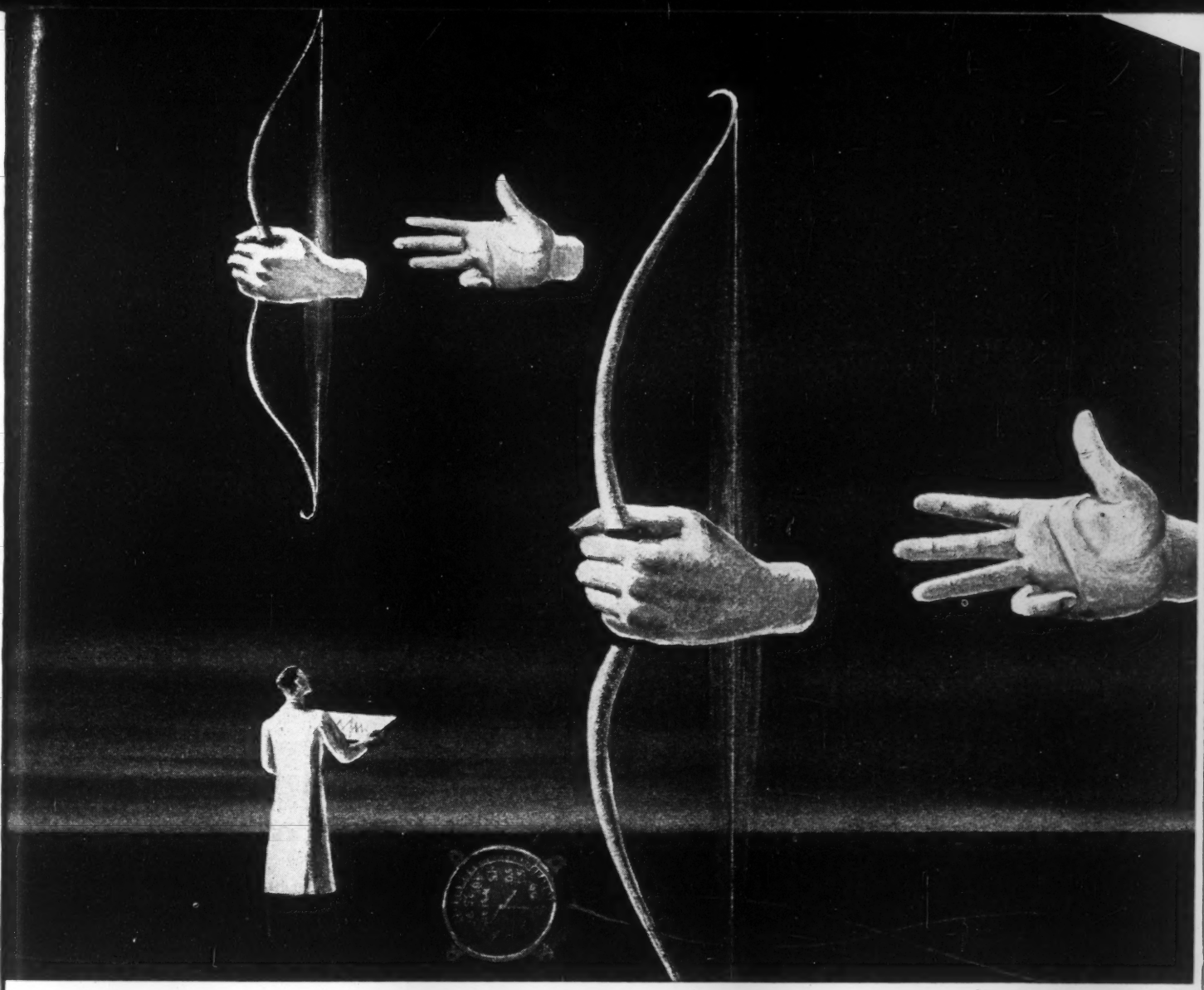

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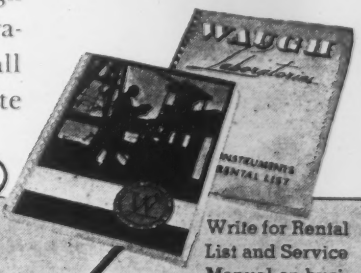

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others on grating theory, mounting, and use, contain all the information necessary to enable one to design a spectroscope for his particular needs, or to choose the proper commercial instrument, of which many types are illustrated and described. The information of most general use to the spectrographer is found in chapters on the history of spectrography, on light sources, on the determination of wave length and of spectral intensity, and on the spectroscopy of the infrared and the extreme ultraviolet. The concluding chapter, on spectrochemical analysis, reviews in fifteen pages our present day knowledge of this many sided subject. By a careful reading of every sentence in this chapter one may determine whether his knowledge of the subject is thorough and up to date.

The work will prove to be invaluable to those interested in the design of spectroscopes, and the book should be available to all who have problems in chemical analysis. In no other single treatise are to be found all of the scores of useful suggestions which result from the author's long and successful operation of optical instruments.

—KEIVIN BURNS, *Astronomer, Allegheny Observatory, Pittsburgh.*

CHEMICAL SPECTROSCOPY. By WALLACE R. BRODE. John Wiley & Sons, New York, 1943. Cloth, 5½ × 8¾ inches, xii + 677 pages. Price $7.50.

A spectrographer who has used the first edition is pleased to see the tables of wavelengths of the elements extended to both shorter and longer waves, and to find that the M I T line intensities have been used in place of the somewhat unsatisfactory intensity data of the first edition. (Unfortunately, the typographical error "Cu 2592 intensity 1000" is copied from M I T.)

As in the first edition, the text is arranged so that one may learn the use of either emission spectra or absorption spectra without necessarily following through the details of both. And for the student, the later edition contains more detailed instructions for the performance of quantitative analysis. The most commonly used types of prism spectrograph are described fully and their adjustment is treated in detail. Reference is made to the grating spectroscope and its use. The student is guided in the choice of the proper source and in the selection of the most efficient auxiliary apparatus for each problem. The most useful types of densitometer and other measuring devices are illustrated and their use is explained.

The plates of the iron spectrum with the positions of the useful lines of other elements are particularly helpful in connection with general analyses.

In this book the treatment of the theory of molecular spectra, and illustrations of the possibilities of analysis by means of absorption spectra, are better designed for student use than in any other treatise known to the reviewer. The book is helpful to the teacher of any course in spectroscopy and it has already won a well-earned place in most analytical laboratories.

—KEIVIN BURNS, *Astronomer, Allegheny Observatory, Pittsburgh.*

REPORTS ON PROGRESS IN PHYSICS. Volume VIII (1941). WILFRID B. MANN, General Editor. The Physical Society, London, 1942. Cloth, 7 × 10 inches, 372 pages. Price $5.25 including postage.

Our review of Vol. VII of this series concluded as follows: ". . . and order Vol. VIII in advance! . . ." None of those who followed this advice could have been disappointed in any way, for this volume represents, as did its precursors, a balanced choice of timely subjects and a successful round-up of eminent authors.

Timeliness of subject and eminence of author are both exemplified by this volume's first article. Professor Born's essay (it is more of an essay than a report of work done) is even more than timely: it is prophetic. It is timely because in recent years the teaching of theoretical physics suffered severe curtailments in most of the world's universities—first in Germany, then in Spain and the other fascist countries, finally in the civilized countries overrun by the barbarians.

This essay is prophetic because our own country's numerous universities, which did not neglect pure science before the 7th of last December while we were the Arsenal of Democracy, will undoubtedly be "drafted" as training centers now that we are fighting—now that we have to raise and equip huge armies, naval forces and air armadas —now that we have to convert our automobile and other industries into war plants—now that we have to build and man new shipyards and factories of entirely new types. Yes, nearly every department of theoretical physics will have to be converted into an invention-and-development project working feverishly on new Infantry weapons, new fog-piercing Signal Corps devices, new high-temperature materials for new types of airplanes, etc. It is no military secret that this conversion has already begun here. It probably has been completed in England; and perhaps that is why Dr. Mann gave the place of honor in this volume to Dr. Born's article—because this article is not a catalog of recent discoveries but in part an analysis of conditions and in part an inspiring statement of temporarily-neglected ideals!

As we did for the previous volumes, we list the reports in Vol. VIII with a count of pages, references cited and other data for each:

The teaching of theoretical physics in universities.* By M. Born: 10 p.

The theory of the specific heat of solids.* By M. Blackman: 19 p., 50 refs.

High-speed centrifuging.* By J. W. Beams: 19 p., 104 refs.

Applications of spectroscopy to combustion.* By A. G. Gaydon: 20 p., 135 refs.

Friction between solid bodies.* By Robert Schnurmann: 19 p., 3 p. of halftones, 54 refs.

The general physical constants. By Ray-

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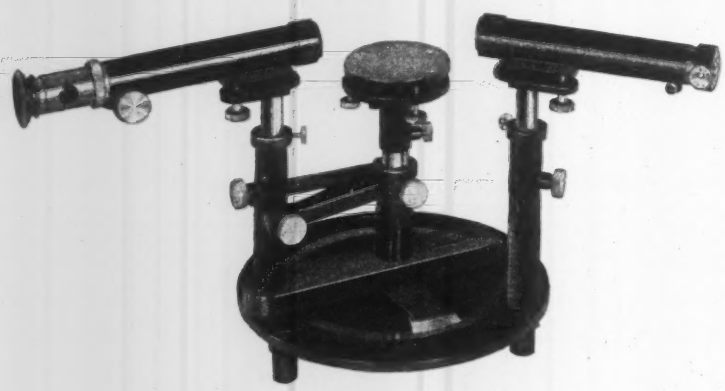

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mond T. Birge: 44 p., 3 tables, 121 refs.

Recent television developments.* By V. K. Zworykin and R. E. Shelby: 50 p., 15 figs., 83 refs.

Instrumental technique in astrophysics.* By A. Hunter: 14 p., 28 refs.

Dispersion in the far infra-red. By Lotte Sellner: 12 p., 22 refs.

The M.I.T. wavelength project.* By George R. Harrison: 21 p., 21 refs.

Molecular electronic spectra, dispersion and polarization (the theoretical interpretation and computation of oscillator strengths and intensities). By Robert S. Mulliken and Carol A. Rieke: 43 p., 7 tables, 69 refs.

Symmetry properties of nuclear levels. By Eugene P. Wigner and Eugene Feenberg: 44 p., 5 tables, 9 figs., 123 refs.

Photometry. By H. Buckley: 20 p., 96 refs.

Discharge phenomena in gases. By R. Winstanley Lunt, A. von Engel and J. M. Meek: 30 p., 143 refs. in 4 parts.

[Asterisks (*) denote subjects not covered in preceding volumes.]

This volume is the first one with an index at the back. It is an author index—specifically an index of the authors cited in the thirteen bibliographies. The need has been and is for a competently-prepared subject index; but this reviewer knows from experience that only a physics-trained librarian could be entrusted with this work, that it would take one man at least three weeks to do the first part of the job, and that the details would take another two weeks even in the most competent hands. So packed with information is each annual volume of this series that a really adequate subject index would probably fill ten pages. What this reviewer now hopes for is a Cumulative Index to the first eight volumes. Here is a project which could be carried through in America where Technical Librarians are so numerous and so well organized!

Nevertheless we can repeat again: "No physical research laboratory is completely equipped if it lacks this volume and its precursors." —M. F. BEHAR

DIRECT CURRENT CIRCUITS. By EARLE M. MORECOCK. Rochester Technical Series, Harper & Bros., New York, 1944. Cloth, 6 × 9 inches, 387 pages. Price $3.25.

This text has been prepared by the author with the specific purpose of making possible the training of students in industrial classes on basic electricity. The text is provided primarily for Industrial and Extension Course Schools where students may not have had the advantage of extensive mathematical training. The student entering this course is only required to possess a working knowledge of algebra and logarithms. A complete avoidance of higher mathematics has been attained in the writing without injuring the general texture of the technical material treated. In keeping with the general series of technical texts prepared by the faculty of the Rochester Athenaeum and Mechanics Institute, the text is well-rounded and clearly written, although in some aspects admittedly brief, the subject-matter being chosen with a view to providing a well-rounded training within the limits of definite occupational objectives. As is typical of texts of the briefer and less formal variety, a good deal of laboratory work is combined with the training course. A foreword gives suggestions for study and laboratory procedure, with some brief notes on the use of measuring equipment.

The opening chapter, "Elementary Electrical Circuits," sketches the historical background, with some underlying theory. The theoretical exposition, unfortunately, is not always correct in the light of modern-day physics. Reliance is placed on the usual hydraulic analogues for potential difference, current flow and resistance.

Circuit elements used in figures are in confirmation with the standards chart of the A.I.E.E., while Ohm's Law is well covered. Problems in resistance networks are well handled through the use of simple conductance formulae, while a well-chosen series of review questions, problems and laboratory experiments round out the chapter.

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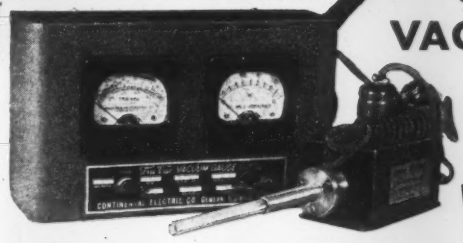

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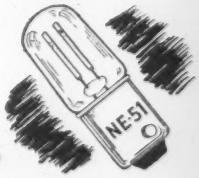

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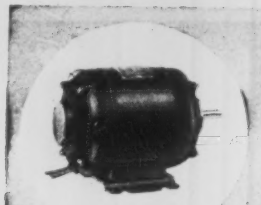

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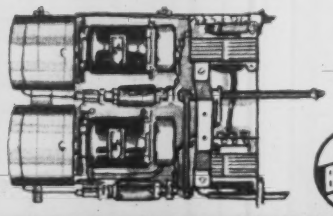

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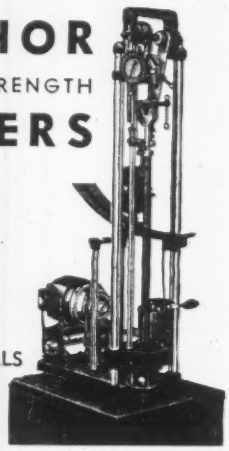

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ered from a practical standpoint with clear photographs and line drawings illustrating the usual basic phenomena. Brief laboratory experiments, review questions and problems terminate the subject.

A brief chapter on measuring instruments and methods describes functions of measuring equipment, ranging from the d'Arsonval galvanometer to the Wheatstone bridge and laboratory potentiometer. Later chapters on conductors, insulating materials and batteries are briefly covered with pertinent review questions and problems appended to each chapter.

Chapter seven, "Other Electric Circuits," is of most importance to the serious student the author giving detailed use of Kirchhoff's Laws and their application to network solution involving direct currents and potentials. Detailed workings of problems are included with step-by-step working of the simple algebraic equations involved, without recourse to determinant methods.

A well-conceived chapter on the magnetic circuit and electromagnetic induction makes available calculation of problems entailing magnetic phenomena, while some space is given to brief description of measuring apparatus common to the magnetic laboratory.

The final chapter, on Electrostatics, is well-written, with concise and brief description of charge and capacitance calculation. Review questions, problems, and some laboratory experiments terminate the chapter.

An appendix treats laboratory report writing and graph plotting; while a significant tables concerning resistivity and temperature coefficient of metals and alloys, wire tables, and tables of electrical symbols and conversion factors are included.

A nicely prepared index terminates the volume. The reviewer has noted some typographical errors, while some re-editing of the technical material is recommended. Printing is legible on good paper stock and in general the volume should be of interest to prospective students in accelerated training programs.

—THEODORE A. COHEN, *Vice-Pres. Engineering and Research, Wheelco Instruments Co., Chicago.*

ALTERNATING CURRENT CIRCUITS. By EARLE M. MORECOCK. Rochester Technical Series. Harper & Bros., New York, 1942. Cloth, 6 × 9 inches, 175 pages. Price $2.75.

This companion volume to "Direct Current Circuits" by the same author is intended as a succeeding volume in the series of technical tracts prepared by the faculty of the Rochester Athenaeum and Mechanics Institute for the instruction of industrial classes. "Alternating Current Circuits" has been prepared for those students whose mathematical background is, of necessity, incomplete and does not extend beyond a working knowledge of algebra and trigonometry. It is, of course, a pre-requisite that the student have a good knowledge of work in direct current and magnetic circuits. Although even a cursory knowledge of calculus is normally a requirement for a well-founded study of the usual alternating current phenomena, the author has admirably avoided it. In those cases where a-c. circuit concepts and equations customarily require the calculus, such exposition is handled graphically. Since the volume is for industrial classes whose members may have had no previous formal training, many suggestions for study and laboratory procedure are included. This is to be highly commended. A foreword giving suggestions for laboratory procedure and technique is drawn briefly and concisely. It would seem, however, that this foreword could be expanded considerably in the interest of the student.

The opening chapter is concerned with the commercial uses of a-c. power, with brief description and examples of simple phenomena. In the reviewer's opinion, some of the included material might be deleted in favor of material more significant to the early study of a-c. circuits. Review questions, problems, and significant laboratory experiments complete the chapter.

The following chapter, "Vectors and Complex Quantities," is of scope sufficient for the purpose intended. Vector diagram struc-

ire and methods of working trial problems re well illustrated, while complex number tation is well described. The reviewer was isappointed to note that this chapter did ot include a description of process of tele- oping and quading, while trigonometric nctions and logarithms of complex num- ers seem necessary to the student. A fur- ier expansion of the chapter should include more detailed description and use of the nvolution and evolution of the complex mber, which is only cursorily treated. Of ajor interest to the student are the ex- mples given of various problems, and step- by-step solutions therefor.

The remainder of the book is divided nto phenomena in single-phase and poly- hase systems, respectively. All subjects are easonably well illustrated by appropriate ircuit diagrams and vector representation. Although the reviewer is not in complete ccordance with the over-simplified wording in some explanatory statements, it may be hat this was desired by the author in view of the training program contemplated.

Polyphase problems are well worked out through the use of vector algebra and com- plex number notation, with review questions and problems appended at the end of the chapter.

An appendix on laboratory report writing is a thoughtful inclusion, while a second appendix treats graph plotting and data gathering. Tables of natural trigonometric functions as well as squares of numbers are included. The index is rather brief and could be expanded considerably. A bibliog- raphy would be advantageous to the student who desires references. Some editing could be performed to good purpose, especially in the case of certain equations. Few typo- graphical errors were noted. The writing is clear and concise, although admittedly brief, with clear, legible printing on paper stock of good quality. The book should be a good addition to the beginning student's collection on electrical subjects.

—THEODORE A. COHEN, *Vice Pres. Engineering and Research, Wheel- co Instruments Co., Chicago.*

EXPERIMENTS IN ELECTRONICS AND COMMUNICATION ENGINEERING. By E. H. SCHULTZ and L. T. ANDERSON. Harper & Brothers, New York, 1943. Cloth, 6 × 9 inches, 380 pages. Price $3.00.

The authors have presented a highly com- mendable compilation of experiments for laboratory work in Electronic phases of Communication Engineering. The collection is broad in scope and amply reflects the ex- perience and ability of the author educators to present student material in a complex art. The material is expressly prepared as guidance for projected laboratory work in accelerated training programs in Electron- ics, High- and Ultra-high Frequency Tech- nique. Such accelerated programs for train- ing of Signal Corps specialists have made necessary a considerable condensation in laboratory work but, in the opinion of the reviewer, the skillful selection and exposi- tion of the subject-matter has resulted in no pertinent omissions, such as are frequently encountered in accelerated technical train- ing curricula.

The opening chapters are concerned with such basics as laboratory technique, meas- uring instrument application and manipu- lation, apparatus protection and cautions, data gathering, observation and significance, while tabulation and curve plotting is stressed as an important portion of experi- mental deduction.

Such basics are rare to a volume of lab- oratory experiments and should not only stand the trainee in good stead, but should be of great benefit to the practicing engineer whose basics have become somewhat rusty with disuse. Tables of electrical symbols in Electronics and Communications are con- tained in the collection of useful data which also includes a great many photographs of significant components of communication circuiting.

Common laboratory apparatus, such as direct-current and alternating-current indi- cating instruments are described, while uses

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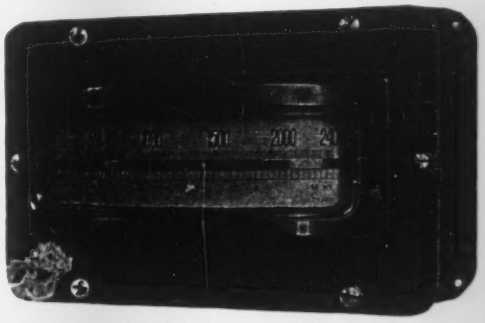

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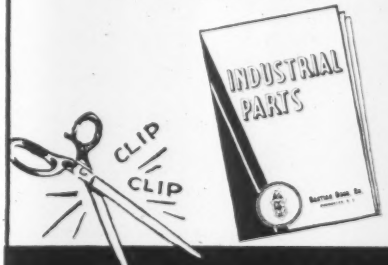

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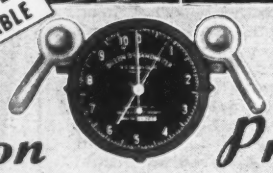

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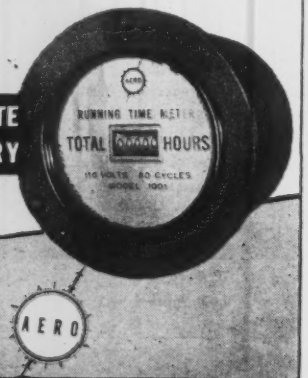

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of the ordinary Wheatstone bridge in the experimental laboratory are briefly covered.

Advanced apparatus, such as capacitance, inductance, and impedance bridges, is cursorily covered with scope sufficient for the limitations of the intended work.

More significant work for the advanced student in Communications, such as Gain Measurement, Network Theorems and Transmission-line problems, is skillfully set forth.

A chapter dealing with cathode-ray oscillograph uses, applications, and condensed theory, is nicely assembled, and is placed in a significant portion of the curricular assembly.

Laboratory work on oscillators and amplifiers might be expanded to some extent, but probably at the expense of other pertinent materials, such as the fine data on such later Ultra-high Frequency devices as the Klystron, and other velocity-modulated oscillators.

A final chapter on Transmission-line work, including antenna arrays, field patterns and wave guides, rounds out a well-conceived and executed whole. Individual experiments include, where pertinent, brief mathematical exposition with significant formulae at secondary-school algebra and trigonometry level. Brief bibliographies of important references are available in the form of experiment terminating footnotes.

A rather limited index (which could be greatly expanded) terminates the book, while it would seem that some care in editing of the data presented would have prevented such obvious errors as the given expression for the square wave form:
$e = E \sin \omega t + E/3 \sin \omega t + E/5 \sin \omega t + \ldots$
rather than:

$$e = \frac{4E}{\pi} [\sin \omega t + \tfrac{1}{3} \sin 3\omega t + \tfrac{1}{5} \sin 5\omega t + \ldots]$$

Some circuit diagrams and wording require correction, but considering the scope of the work, and the possible issuance of a satisfactory errata sheet, the work should find a worthy place in the library of both student and professional engineer.

The printing is highly legible, the style of expression clear, and mathematical expressions where used, nicely expounded.

—THEODORE A. COHEN, *Vice-Pres. Engineering and Research, Wheelco Instruments Co., Chicago.*

ELECTRONICS FOR BOYS AND GIRLS. By JEANNE BENDICK. McGraw Hill Book Co., New York, New York, 1944. Cloth, 5½ × 8 inches, 144 pages. Price $1.50.

A cleverly written volume, well-conceived and covering a sufficient subject breadth to enable the reader to get a broad vista of the wonders of Electronic Mechanism without struggling through a ponderous tome, this book is written in the popular manner with an interesting simplication of language and technical terminology. The author has put within the grasp of the average teen-age child a large fund of knowledge. A facile ability for illustration, by means of about 200 amusing hand-drawn sketches, puts the antics and migrations of the electron into the realm of faery province.

Such interesting and entertaining statements as "The smallest thing you have ever seen is millions of times bigger than an Electron," opening the first chapter of the book, are among many informal chatty comments the author uses to construct a cohesive and colorful panorama of a vast art.

The chapter contents range from "What is an Electron" through "Electron Mechanism in Industry," to "Electronic Development of the Near Future."

Although the book is not meant as a scientific text by any manner of means, its method of presentation and the scope of the material should make it amusing and instructive reading even to the mature layman. A nicely arranged glossary, a bibliography, and a well-prepared cross index, terminate the book.

—THEODORE A. COHEN, *Vice-Pres. Engineering and Research, Wheelco Instruments Co., Chicago.*

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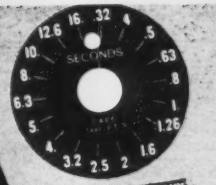

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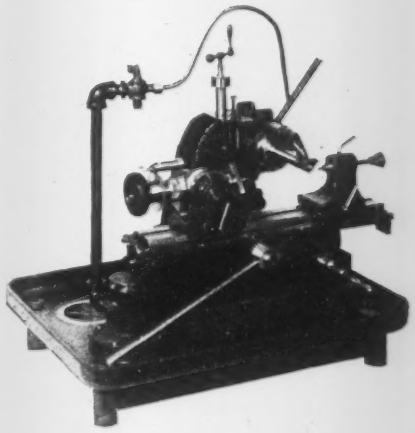

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INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place	Subject	Speaker
Atlanta, Georgia	Georgia Society for Measurement & Control	Robert E. Geminert, P.O. Box 1714, Atlanta				
Baltimore, Maryland	Baltimore Industrial Instrumentation Society	J. J. Seglets, 35 S. Potomac St., Baltimore 24		Engineers Club, 6 W. Fayette St., Balto.		
Chicago, Illinois	Chicago Society for Measurement & Control	A. J. Butler, c/o IHC, 2626 W. 31st Blvd., Chicago	Apr. 2(B)	M&M Club, 237 Merchandise Mart	"Behind the Instrument Dial"	L. F. Parachini, Weston Elec. Instr. Co.
Cleveland, Ohio	Cleveland Instrumentation Society	W. A. Stubblefield, 2085 W. 104th St., Cleveland 2		Cleveland Engineering Society		
Fort Worth, Texas	Fort Worth Electronics Club	Ralph Ely, 1116 E. Arlington, Fort Worth		Texas Hotel, Fort Worth		
Gulf Coast (Texas)	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Texas				
Hartford, Conn.	Hartford Society for Measurement & Control	S. J. Zelle, Bridgeport Thermostat Co., 1225 Connecticut Ave., Bridgeport, Conn.	Mar. 20(B) Apr. 17(B) May 15(B)	Bond Hotel Bond Hotel Bond Hotel	Electronics, Fad or Servant Instruments in Crime Detection Automatic Temperature Control	Dr. Paul G. Weiller Speakers from Conn. State Police C. O. Fairchild, C. J. Tagliabue Div.
Kansas City, Missouri	KC Industrial Instrumentation Society	Gordon H. Burke, 1527 Broadway, Kansas City, Mo.		Bluebird Cafeteria		
Los Angeles, Calif.	California Instrument Society	M. D. Pugh, 2989 Lincoln Ave., Altadena, Calif.				
Newark, N. J.	Society for Measurement & Control (New Jersey)	Robt. H. Gray, 1 Whippoorwill Way, Mountainside, N.J.	Apr. 3(B)	Essex House	Problems in Unionized Instrument Department	J. J. Maguire, Wright Aero. Co.
New York, N. Y.	New York Society for Measurement & Control	H. L. Hildenbrand, 207-07 33d Ave., Bayside, L.I.,N.Y.	Mar. 27(B)	Columbia U. Men's Faculty Club, 400 W. 117th St.	New Instrumentation Methods in Petr'm Ind'y	Dr. W. S. Sweeny, Esso Labs.
N. Indiana	Northern Indiana Soc. for Measurement & Control	K. M. Frame, 25 Ruth St. Hammond, Indiana				
Philadelphia, Pa.	Philadelphia Society for Instrumentation	G. E. Gress, c/o ATC, 34 E. Logan St., Philadelphia	Mar. 21(B)	Engineers Club, 1317 Spruce St.	Instruments for Photographic Recording	F. A. Tompkins, Eastman Kodak Co.
Pittsburgh, Pa.	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh 13	Mar. 26(B) Apr. 23(B) May 28(B)	Roosevelt Hotel Roosevelt Hotel Roosevelt Hotel	Combustion Control Surface Finish Instruments Process Control	W. Pray, Askania Reg. W. Mikelson, G.E. W. B. Heinz, Cochrane
St. Louis, Mo.	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.				
Toronto, Ontario	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co.		Diana Sweets, 188 Bloor St. W., Toronto		
Washington, D. C.	Instrument Society of Washington	W. A. Wildhack, National Bureau of Standards, Wash'n	Mar. 20(D)	Interior Dep't Auditorium		
Wyandotte, Mich.	Instrument Society of Wayne County	D. J. McCloskey, 116 Oak St., Wyandotte, Mich.	Mar. 26(B)	West Mound Methodist Church	The Foxboro Electronic Potentiometer	Don M. Nielsen

(A) Meeting at 7:30, no dinner (B) Dinner at 6:30, meeting at 8 (C) Dinner at 7, meeting at 8 (D) Meeting at 8, no dinner

CHICAGO

The February 5th meeting of the Chicago Society for Measurement and Control was well attended to hear a talk by Mr. W. J. McDonough, Sales Manager of Northern Equipment Company of Erie, Pennsylvania.

Mr. McDonough gave us a most interesting talk on The Theory of Boiler Feed Water Control along both theoretical and practical lines. He made use of a number of slides showing various graphs and pictures of installations of various types of boiler feed water level controls and the points discussed were very enlightening.

The graphs portrayed very clearly the relationship of the requirements of the boiler for feed water requirements as well as the close relationship of feed water controls for variable load conditions.

Various types of feed water controls were covered in the explanation given by Mr. McDonough with the use of a number of slides. These covered the simple types, as well as the more complex types with greater flexibility for feed water control with extreme load change requirements.

In the discussion that followed the delivery of Mr. McDonough's talk, the points occasioned a very lively type of interest and the discussions covered installations ranging from stationary units to marine types.

Mr. McDonough's talk on boiler feed water control was very much appreciated by the Chicago Society and many of the points which he brought out in his discussion will no doubt be beneficial to many of the members and guests who were present for the meeting. —GORDON R. THOMASON

KANSAS CITY

At the January 30 meeting of the Kansas City Industrial Instrumentation Society, new committee members were appointed for the following committees:

Finance Committee: Gordon H. Burke (Burke Engineering Company) *Chmn.;* Baker Manley (J. F. Pritchard & Co.); Roy Carns (Sinclair Refinfiing Co.).

Constitution & By-laws: Joe Spacek (Aluminum Company of America) *Chmn.;* Larry Siler (Hercules Powder Co.); R. J. Hunter (Standard Oil Co.).

Membership Committee: Robert Cooke (Westinghouse) *Chmn.;* Gene Preston (York Midwest Corp.); Oliver Boutros (Boutros Instrument Co.).

Meetings & Programs: Lester Johnson (Sinclair Refining Co.) *Chmn.;* Bash Nichols (Pratt & Whitney Aircraft); James Glenn (Pittsburgh Equitable Meter Co.).

Rhein Benninghoven of Republic Flow Meters Company presented a basic lecture on "Primary Flow Devices." Benny did a bang-up job of explaining the history, development and application of the various primary flow devices.

Our Quiz Kids, Baker Manley (J. F. Pritchard & Co.); J. D. Marsh (Corn Products); R. J. Hunter (Standard Oil); R. R. Cox (Phillips Petroleum); hit all of them for a home run. James Pugh of Standard Oil Company had a tough one which was a little too hot for the boys to handle.

Our guest speaker, William P. Myers of the Brown Instruments Division of Minneapolis-Honeywell Regulator Co., came over from St. Louis to explain the new "Electronik" method of temperature measurement. If anyone wants an explanation of the usually complicated theory of electronic circuits so that the average man can understand them, just call on Bill, for he can certainly do it. It was a grand talk, and very much appreciated by all members and guests, totaling 56. —W. A. REICHOW

KANSAS CITY

At the February 27th meeting of the Kansas City Industrial Instrumentation Society, Joe Spacek of Aluminum Company of America presented a basic lecture on "Prevailing Errors Resulting from Using Compensating Lead Wire with Chromel-Alumel Thermocouples." Joe did a swell job of demonstrating how a little night work with some of the Bureau of Standards reports can enable instrument men to solve some of their everyday problems on pyrometry.

Our Quiz Kids, Harold Sullivan (Sullivan-Mears), Robert Hunter (Standard Oil), Henry Risk (Hercules Powder), and Larry Siler (Hercules Powder), just couldn't be stumped.

E. K. Welch, the St. Louis representative, introduced our guest speaker, Dr. W. N. Greer of Leeds & Northrup Company. Dr. Greer's talk on pH measurement and control created considerable interest and brought up many questions and answers in the hour's discussion which followed.

Approximately sixty members and guests attended this meeting. Bill McQuilkin of J. F. Pritchard & Company introduced a special guest, Captain K. C. Chow of the Chinese Air Forces. —W. A. REICHOW

LOS ANGELES

On Tuesday evening, February 6th, at the Town House in Los Angeles, the third organizing meeting of the California Instrument Society was held, with about sixty-five present. A constitution, tentatively adopted at the previous meeting, was approved. Officers and councillors were elected for the ensuing year:

President: Wm. B. Warren, Warren & Wunderly.

Vice President: W. K. Rieber, Frank Rieber, Inc.

Continued on page 208

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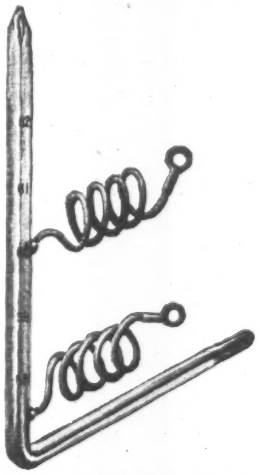

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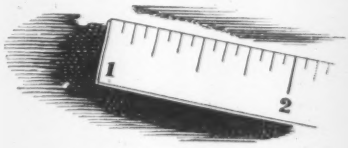

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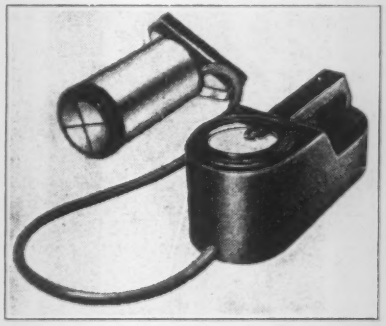

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Councillors for two years: A. O. Beckman, National Technical Labs.; George Downs, California Institute of Technology.

Councillors for one year: Frederick Ireland, General Radio Co.; Richard G. Leitner, Frank Rieber, Inc.; J. F. Drescher, Pyramid Construction Co.

Following the business meeting a film on the "Story of Metal Bellows" was shown. Regular monthly meetings are planned.

—M. D. PUGH

PITTSBURGH

The February meeting of The American Society for Measurement and Control was held at Roosevelt Hotel on Monday evening, February 26. The meeting was conducted by A. H. Shafer of The Foxboro Company in the absence of President R. J. S. Pigott and Vice President Paul G. Exline.

A report on the Chicago meeting for the National Organization was submitted by A. H. Shafer (Delegate), Richard Rimbach (Alternate delegate). The name of the National Society as selected by the delegates at Chicago is to be "Instrument Society of America" and a meeting of chapter delegates will be held in Pittsburgh on April 28, 1945.

An announcement was made by the Secretary regarding the Exhibit and Conference to be held September 17-21, 1945. A total of 90 booths have been sold by the Exhibit Committee to 61 Exhibitors for $10,295.00. Only one booth remains unsold.

J. A. Pellettere, Chief Instrument Engineer of Gulf Oil Company spoke on the subject of "Inter-connected Control Instruments." The speaker covered a plurality of instruments showing some 50 slides representing several manufacturers. Included were some interesting features of ratio instrumentation as applied to the refinery where process, combustion control and valve factors are primary problems. Mr. Pellettere has classified inter-connected instruments according to the following table:

1. Combat poor system or valve characteristics.
2. Simple ratio instruments.
3. Provide selectivity or override.
4. To provide invisible limits, namely limits actually built into control instrument
5. Provide safety features
   (a) Limits
   (b) Override
      1. Instrument in service
      2. Double diaphragm
      3. Selective relay
   (c) Sequence timer
6. Compensate important variables.

The dinner preceding the meeting was attended by eighty members and guests; and there were 140 for the meeting.

—L. M. SUSANY

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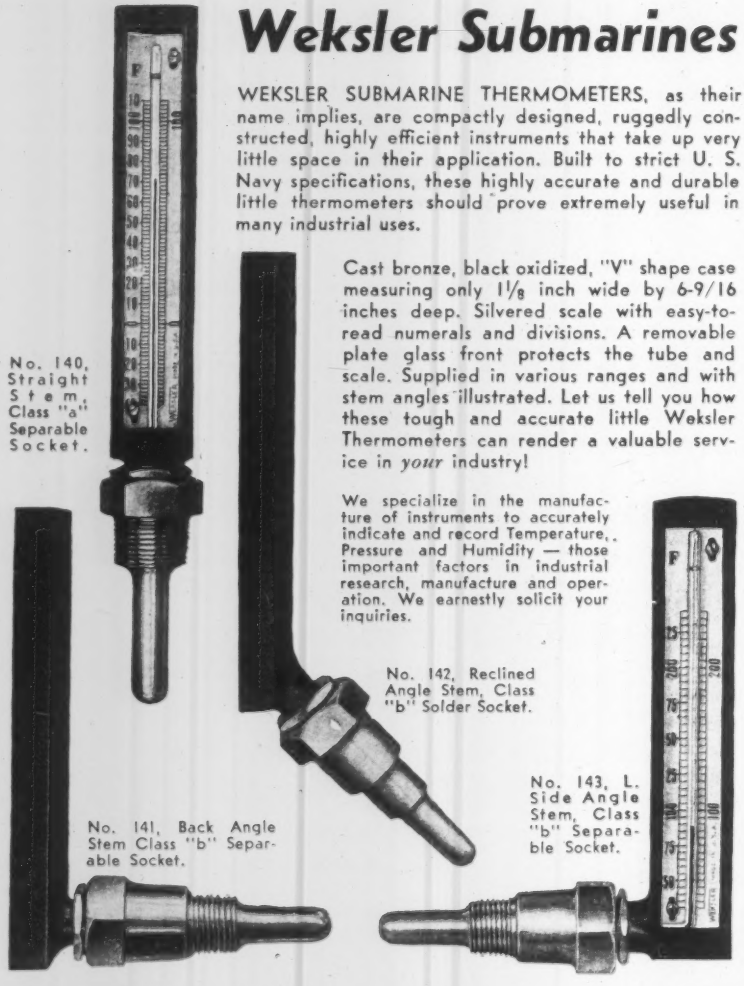

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WYANDOTTE

The February meeting of the Instrument Society of Wayne County was one of our best. There was the usual grand country dinner served by the ladies of the church where we meet, namely the West Mound Methodist Church.

Our library shelves are now established and everyone interested is urged to look over our collection and make suggestions as to other books and catalogs to be added.

There was discussion of the proposed national instrument society, and a motion was passed to send Mr. Baker, our President, as a delegate to the Pittsburgh meeting on April 28.

The group was much interested in Mr. Early's slides and talk on Askania Control. The fundamental principle and the application to combustion problems and other pressure and ratio jobs brought out numerous questions and much discussion.

—JOHN MACPHERSON

WASHINGTON

At the February meeting of the Instrument Society of Washington, Mr. L. F. Crabtree, of the Automatic Electric Company, gave a discussion of the Design and Application of Electromagnetic Relays, illustrating the talk with diagrams and design charts. He showed schematic drawing of special circuits utilizing relays for counting, interlocking, and cycling.

An informal communication on Design of Corrugated Diaphragms was presented by Dr. W. G. Brombacher, Chief of the Aeronautic Instruments Section of the National Bureau of Standards.

The first issue of the Society's newsletter was distributed during the month to the membership, which now totals more than two hundred.

—W. A. WILDHACK

NEW SPECTROGRAPHERS' SOCIETY

On January 22, the first meeting of the Detroit Spectrographers' Society was called to order by Mr. Jess Toth, Chairman Protem, at the Rackham Memorial Building.

This newly formed Society has for its purpose the dissemination of knowledge pertaining to spectrochemical analyses and to assist in the development of improved methods and technique as its affects not only the science of spectroscopy but the related sciences such as chemistry and electronics.

The meeting was devoted to organization and the following officers were elected:

Chairman: William Edgar, Federal Mogul Corp., Detroit.

Vice Chairman: Dean E. Shields, Packard Motor Car Co., Detroit.

Secretary: M. M. White, Harry W. Dietert Co., Detroit.

Treasurer: E. A. Boettner, Wyandotte Chemical Corp., Wyandotte, Mich.

Executive Council: R. E. Nusbaum, General Motors Research Laboratory, Detroit; John Schuch, Harry W. Dietert Co., Detroit; William Sundwick, Ternstedt Mfg. Division, Detroit.

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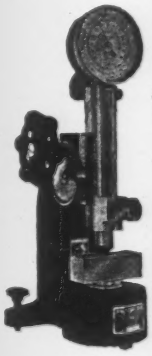

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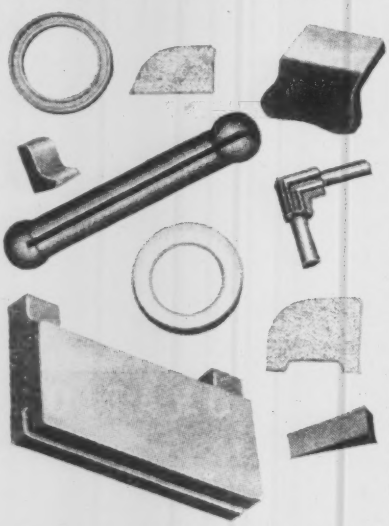

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on the facing page.

M-66 **Portable Electrical Testing Instruments.** 4-sheet 8½" × 11" Bulletin No. 112C describes and gives specifications of the following: (1) Model 710 Volt-Ohm-Milliammeter; (2) Model 560 Industrial Analyzer; (3) Model 590 four-neon-bulb type Voltage Tester; (4) Model 610-B Meg-O-Meter direct-reading insulation tester. Superior Instruments Co., 227 Fulton St., New York 7, N. Y.

M-67 **Aircraft Controls.** 12-page 8½" × 11" Bulletin No. 30-D illustrates and describes aircraft relays and control devices. Includes enlarged cut-away section, condensed rating table and index, and dimensional drawings. Hart Manufacturing Co., Hartford, Conn.

M-68 **Transformers, Reactors, Filters, and Electronic Components.** 12-page 8½" × 11" pamphlet gives detailed descriptions including prices and application of products manufactured by the company. Audio Development Co., 2833 Thirteenth Ave., South, Minneapolis 7, Minn.

M-69 **Testing Machines for Plastics.** 16-page 8½" × 11" Bulletin No. 23 lists various testing machines available and their applications in testing plastics for tension, compression, flexure, stiffness, flow and distortion. Describes operating principle, magnification recorder, and capacity range. Tinius Olsen Testing Machine Co., 500 N. Twelfth St., Philadelphia, Pa.

M-70 **"Radio's Master."** 1057-page 7½" × 10½" cloth-bound Consolidated Catalog, Edition 10, covers products of a large number of manufacturers and dealers, is described as the official parts and equipment manual of the radio and electronic industry. Practical reference and buying directory with illustrations, descriptions, specifications and prices. Lacks consecutive paging but is divided into lettered sections, each paged. Most useful is the General Index at the back. Sun Radio and Electronics Co., 212 Fulton St., New York 7, N. Y.

M-71 **Vibration Measuring Instrument.** 8-page 8" × 10½" Publication GEA 4140 describes dial-type indicator and light-beam type indicator for measuring displacement, and vibration-velocity meter. A table of range and accuracy of each instrument, circuit diagram of vibration-velocity meter, principle of operation and guide for proper selection of equipment are included. General Electric Co., Schenectady, N. Y.

M-72 **Universal Fatigue Machine.** 6-page 8½" × 11" Bulletin 206 pictures and describes testing machine which can be used for direct stress or torsional fatigue testing. Accommodates specimens for bending moments up to 200 inch-lb. Leaflet includes detail of operating machanism specifications, cut-away sections and range of accuracy. The Baldwin Locomotive Works, Baldwin Southwark Division, Philadelphia, Pa.

M-73 **Electronic Fluxmeter.** 2-page 8½" × 11" leaflet describes a flux density meter which uses an electronic circuit connected to an indicator to measure field strength. Size and shape of search coils designed for any special condition including measurements of magnets which have no gaps. Description of operating principle, accuracy and construction are included. The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.

M-74 **Time Cycle Controller.** 12-page 8½" × 11" catalog 98154 describes "Flex-O-Timer" adjustable time cycle controller which times sequence and duration of operation involving temperature, humidity, pressure or combinations of each. Explains with diagrams auxiliary timer which fits in same case and is used in typical platen press installations for plastic molding. Also included are photographs of timer and some of its applications. Taylor Instrument Companies, Rochester, N. Y.

M-75 **Floatless Liquid Level and Industrial Controls.** 28-page 8½" × 11" catalog No. 145 describes method of controlling liquid level without floats or vacuum tubes, and explains principle and operation of B/W relay. Contains application diagrams, motor starters, selector switches, special relays, ice-free electrode unit, photographs of special panels and other items. B/W Controller Corp., 2200 East Maple Road, Birmingham, Mich.

M-76 **Resistors and Radiant Heaters.** 4-page 8½" × 11" bulletin describes unit and bank type resistors with glazed steatite core which are shock and salt-spray tested. Heater range up to 1700°F. Also included are additional features of design and electrical data. Techtmann Industries, Inc., 828 N. Broadway, Milwaukee 2, Wis.

M-77 **Null Detector and Tolerance Bridge.** 2-page 8½" × 11" bulletin describes :(1) a cathode-ray tube null detector for a-c. bridge measurements visually; detector has impedance of 1 megohm and a gain of 80 db with input of 100 microvolts. (2) Tolerance bridge accurate to 0.1%, checks a-c. resistance and impedance, capacitance and inductance, can be used as inspection tool. Sherron Electronics Company, Div. of Sherron Metallic Corp., 1201 Flushing Ave., Brooklyn 6, N. Y.

M-78 **Instrument Vibrator,** 4-page 8½" × 11" bulletin 44-E describes a machine which produces circular vibratory motion on a plane 45 degrees to the horizontal. Oscillator driven by ½-h.p. motor to give speeds from 500 to 3000 r.p.m. Bulletin includes specification table, principle of operation, method of suspension and adjustment of center of gravity. Krouse Testing Machine Co., 573 Eleventh Ave., Columbus 3, O.

M-79 **Panel Instruments.** 4-page 8" × 10½" Bulletin GEA-4064 describes 2½" internal-pivot panel instruments having a depth of one inch. Includes tables of ratings and dimensions of d-c. voltmeters, d-c. ammeters, milliammeters, microammeters, specifications and correction-data chart for thermocouple ammeters used on high frequency. Illustrated with photographs and cut-away of views of instrument. General Electric Company, Schenectady, N. Y.

M-80 **Chrono-Tachometers.** 16-page 8⅜" × 10¾" Bulletin No. 128 describes

Instruments for measurement of average speed of rotation. Consists of tachometer indicating approximate speed, revolution counter and timer, together with means for driving from an engine or prime mover. Several models listed with specifications, overspeed protection and dimension sheets. The Standard Electric Time Co., Springfield 2, Mass.

M-81 **Temperature Control Devices.** 4-page 8½" × 11" circular describes temperature controls using principle of expansion of solids operating snap-action switches. Photographs of several models with a temperature range of minus 100°F. to 1400°F. (Special alloy available for higher temperatures.) Can be used as a safety cut-off or controlling temperature. Also included are diagrams of installations and mounting equipment. Burling Instrument Company, 253 Springfield Ave., Newark 3, N. J.

M-82 **Voltage Regulating Transformer.** 4-page 8½" × 11" circular describes Gulow "Vari-Former" designed to provide variable voltage from constant voltage source in increments of 0.75 volt from zero to maximum range without circuit interruption. Can be used as line compensator, motor speed control, temperature control, lighting control or constant current control. Available for single-phase or three-phase circuits. The Gulow Corp., 26 Waverly Place, New York 3, N. Y.

M-83 **Reverse Current Cutout.** 4-page 8½" × 11" Accessory Design Check Chart describes "Eclipse" reverse current cutout designed for aircraft generators, with silver alloy contacts and shielded armature leads. Also includes photograph of cutout, diagram of connections and design chart. Eclipse-Pioneer, Division of Bendix Aviation Corp., Teterboro, New Jersey.

M-84 **High Resistance Pyrometer.** 4-page 8½" × 11" Bulletin No. 40 describes "Elematic" self-contained portable pyrometer for checking radio crystals, in sub-zero temperatures (−85°C.). Instrument has cobalt magnet movement, nickel steel compensator, aluminum pointer and hermetically sealed thermocouple. Also included is a photograph and reproduction of six scale ranges in actual size. Elematic Equipment Corp., 6046 Wentworth Ave., Chicago 21, Ill.

M-85 **Microphone Price List.** Single-sheet 8½" × 11" Bulletin No. 1460 lists twenty-seven carbon, dynamic and velocity types in palm, stand throat, lip, hand and cartridge styles. Pre-catalog listing includes application and date available. Universal Microphone Co., Inglewood, Calif.

M-86 **"The Motorgram."** The 4-page 8½" × 11" January issue of this house organ features three articles: (1) Aero-Electric Power—something new in windmills, (2) Stator Winding and (3) Characteristics of constant speed d.c. motors. Bodine Electric Co., 2250 W. Ohio St., Chicago 12, Ill.

M-87 **Industrial X-ray Unit.** 4-page 8½" × 11" Bulletin S-150 describes self-contained "Searchray" unit which can be used for internal inspection of castings, parts and assemblies. Built-in fluoroscopic screen used in taking radiographs. Also included is a table of penetration and a photograph of unit. North American Philips Co., Inc., 100 East 42nd St., New York 17, N. Y.

M-88 **Portable Motor-generator for Testing.** 4-page 8½" × 11" leaflet describes a radio shielded generator for testing 400-cycle a-c. and 27-volt d-c. instruments. Input 115 volts, 60 cycles, 900 watts (max); output 55 watts at 27½ volts, 230 volt-amperes at 115 volts, 400 cycles. Approved by U. S. Signal Corps and particularly adapted for aircraft industry. Wyse Laboratories, Dayton 2, O.

M-89 **The General Radio Experimenter.** The 8-page 6" × 9¼" November issue

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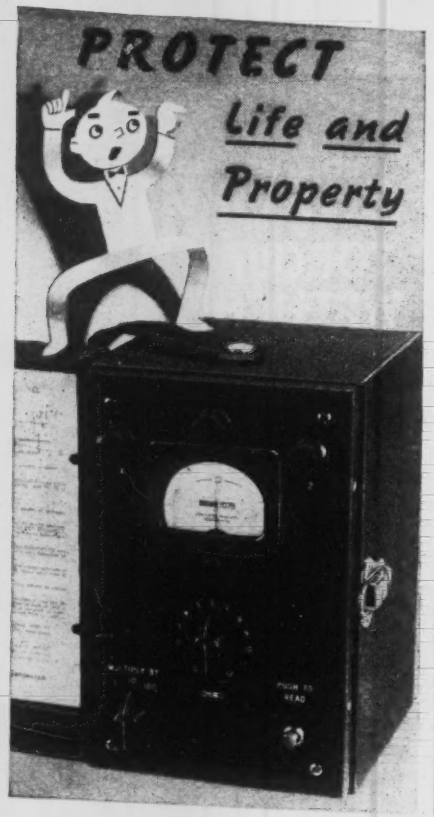

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of this house organ features: (1) A 500-Mc. Oscillator with specifications and circuit diagram, (2) Variacs for 400-cycle operation with dimension sketch and cutaway, (3) Distribution amplifier for standard frequencies, with circuit diagram. General Radio Company, 275 Mass. Ave., Cambridge 39, Mass.

M-90 **The General Radio Experimenter.** This 8-page 6″ × 9¼″ December issue of this house organ features: (1) A d-c. vacuum-tube voltmeter, (2) Mutual inductance measurement with Type 650-A impedance bridge. General Radio Company, 275 Mass. Ave., Cambridge 39, Mass.

M-91 **Fatigue Testing Machine.** 4-page 8½″ × 11″ Bulletin No. 205 describes rotating beam fatigue machine having a capacity of 0-10,000 inch pounds by units of 5 inch-pounds (bending moment). Suitable for specimens of 1″ diameter at 100,000 lbs./in.² and adjustable length from 8½″ to 9½″. Pictured and illustrated diagrammatically showing main functional elements of construction. The Baldwin Locomotive Works, Baldwin Southwark Division, Philadelphia, Penna.

M-92 **Radio and Electronic Book Guide.** 28-page 3¼″ × 6″ booklet provides a list of radio and electronic books classified according to subject matter and also under publisher's name, giving a brief summary of contents. Texts can be used by beginner, student, technician or practicing engineer. Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

M-93 **Electronic Relay.** 8-page 8″ × 10½″ Bulletin GEA-4214 describes G-E electronic relay consisting of electron tube, transformer and electromagnetic relay which can operate an auxiliary relay, solenoid valve or an indicating light. Provides floatless control of levels of many liquids, method of detecting water in gasoline tanks and means of maintaining constant temperature baths. Illustrated with photographs and diagrammatic sketches of various uses. General Electric Co., Schenectady, N. Y.

M-94 **"The Aerovox."** The 4-page 8½″ × 11″ June issue of this house organ features an article entitled "A Dictionary of Capacitor Applications and Recommended Types." It lists in dictionary form the types of capacitors recommended specifically for blocking, bypassing, coupling, filtration, frequency determination, timing and voltage multiplication by reservoir action. The 4-page 8½″ × 11″ July issue of this publication features a technical article on "Capacitor Quality Factors" which is a detailed analysis. Aerovox Corporation, New Bedford, Mass.

M-95 **Portable Electrical Testing Instruments.** 4-page 8½″ × 11″ Instruments Bulletin No. 111 describes Industrial Analyzer which uses same scale for both a-c. and d-c. voltage measurements; also measures current up to 30 amperes and resistance up to 2500 ohms. Instrument has five voltage ranges and two resistance ranges. Also described is "Meg-O-Meter" which measures up to 200 megohms, and a volt-ohm-milliammeter. Superior Instruments Co., 227 Fulton St., New York 7, N. Y.

M-96 **Rotary Electrical Equipment.** 4-page 8½″ × 11″ circular pictures and describes: (1) A series of dynamotors from 10-watt to 500-watt ratings, (2) D.c. Motors up to 5 h.p., (3) Rotary converters up to 2 kva. Elcor, Inc., 1501 W. Congress St., Chicago 7, Ill.

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Passaic, N. J.
GENERAL ELECTRIC CO.
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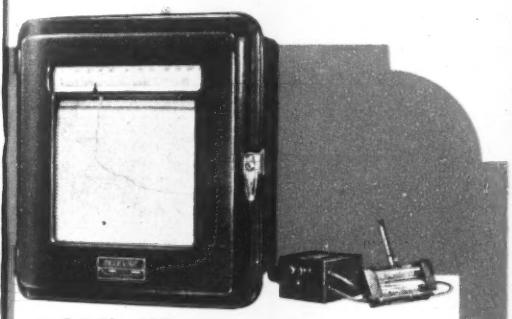
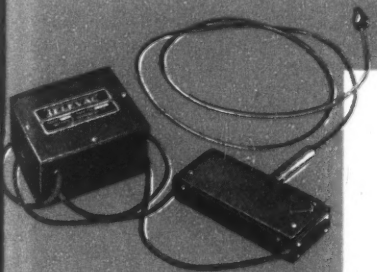


MODEL MR

Model MR Televac provides continuous records of vacuum processes within the range of 0 to 500 microns. Accurate readings are obtainable down to 1 micron. For vacuums better than a micron Model "S" Televac is recommended. This unit is operated by the 500 thermal gauge (see below) and is simple to install. Operates on 115 volts A.C. Due to the stability of this thermal gauge the Model "MR" Televac is adaptable to many vacuum processes, such as vacuum dehydration (penicillin and blood plasma) vacuum tube manufacture, automatic exhaust machines, thermal reduction of metals in high vacuum, laboratory processes, etc.

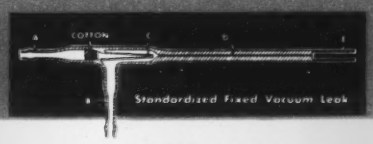
MODEL S TELEVAC

FOR ULTRA VACUUM. This instrument was developed to meet the needs of ultra vacuum processes such as vacuum tube manufacture, deposition of metals and low reflection coatings on glass and plastics and all other processes requiring a vacuum better than 1 micron. To our knowledge no other instrument is available which will accurately indicate and record vacuums down to .001 micron, 10^{-3}mm Hg.) and maintain a constant calibration. Is operated by "500" Thermal Gauge and E-31 Ionization Gauge, (see below) thus providing two Ranges.



MODEL "500" THERMAL GAUGE

The "500" Thermal Gauge maintains a constant calibration in spite of the presence of oil, water, or other contaminating vapors usually found in vacuum systems. All gauges are interchangeable without recalibration and the user is assured of duplicate readings in terms of absolute pressure in microns. Filament current is supplied through a voltage regulator and transformer, thus eliminating varying battery current.



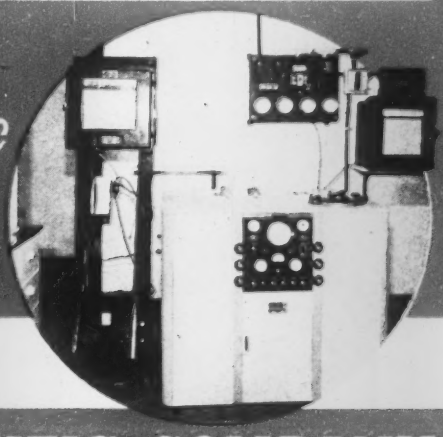
VACUUM LEAK

This new type vacuum leak eliminates many of the troubles found in similar instruments now on the market. Clogging, breakage, time lag, all combine to make it extremely difficult to control the flow of minute quantities of gas. This new type vacuum leak eliminates these difficulties through its inherent design. Constructed of Pyrex glass. Truly a perfect vacuum leak. Three models available: Fixed Flow Rate (standardized), calibrated variable flow rate, uncalibrated variable flow rate.

IONIZATION GAUGE

This "Precision-Fredericks" high vacuum gauge, known as type E-31, is the result of years of research in order to eliminate the "bugs" generally associated with this type of gauge. Electrical leakage is completely eliminated and when used with a moderate high speed pumping system, this Ionization Gauge actually outgasses itself. Filament is protected before and during operation automatically, as current cannot be turned on before pressure of 1 micron has been established and turns off automatically if pressure rises above 1 micron. Gauges are *interchangeable without recalibration* and guaranteed for 1000 hours. Standard E-31 Ionization Gauge comes on scale at 0.4 micron (4×10^{-4} mm Hg) and accurate records are obtainable down to .001 micron (10^{-6} mm Hg).

"PRECISION" Televac
MODEL MR
used in conjunction with Blood Plasma Unit.



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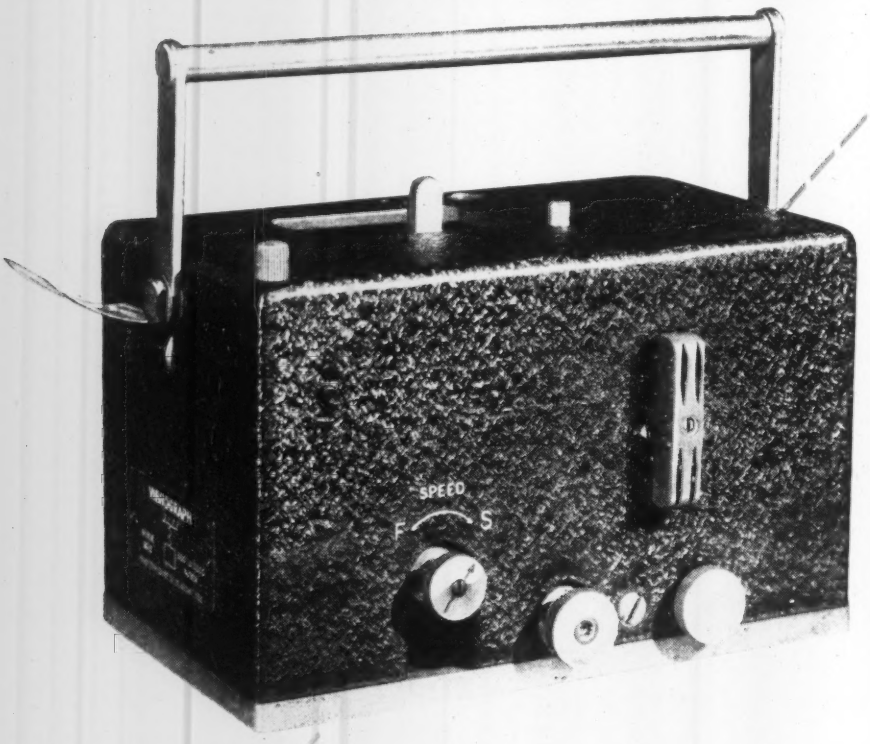

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